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A
DICTIONARY
OF
CHEMISTRY,
ON THE
BASIS OF MR. NICHOLSON'S;
IN WHICH
THE PRINCIPLES OF THE SCIENCE ARE INVESTIGATED ANEW, AND ITS APPLICATIONS TO THE PHENOMENA OF NATURE, MEDICINE, MINERALOGY, AGRICULTURE, AND MANUFACTURES, DETAILED.

BY ANDREW URE, M. D.

PROFESSOR OF THE ANDERSONIAN INSTITUTION, MEMBER OF THE GEOLOGICAL SOCIETY, &c. &c.

WITH AN
Introductory Dissertation;
CONTAINING
INSTRUCTIONS FOR CONVERTING THE ALPHABETICAL ARRANGEMENT INTO A SYSTEMATIC ORDER OF STUDY.

FIRST AMERICAN EDITION;
WITH SOME ADDITIONS, NOTES, AND CORRECTIONS,
BY ROBERT HARE, M. D.
PROFESSOR OF CHEMISTRY IN THE UNIVERSITY OF PENNSYLVANIA.
ASSISTED BY
FRANKLIN BACHE, M. D.
MEMBER OF THE AMERICAN PHILOSOPHICAL SOCIETY, AND OF THE ACADEMY OF NATURAL SCIENCES OF PHILADELPHIA.

IN TWO VOLUMES.

VOL. I.

PHILADELPHIA:
PUBLISHED BY ROBERT DESILVER, No. 110, WALNUT STREET.
1821.

Eastern District of Pennsylvania, to wit:

BE IT REMEMBERED, That on the thirteenth day of October, in the forty-sixth year of the independence of the United States of America, A. D. 1821, Robert Desilver, of the said district, hath deposited in this office the title of a book, the right whereof he claims as proprietor, in the words following, to wit:

"A Dictionary of Chemistry on the basis of Mr. Nicholson's; in which the principles of the Science are investigated anew, and its applications to the phenomena "of Nature, Medicine, Mineralogy, Agriculture, and Manufactures, detailed. By Andrew Ure, M. D. Professor of the Andersonian Institution, Member of the Geological Society, &c. &c. with an Introductory Dissertation; containing instructions for "converting the Alphabetical Arrangement into a systematic order of study. First "American edition; with some additions, notes, and corrections, by Robert Hare, M. "D. Professor of Chemistry in the University of Pennsylvania: Assisted by Franklin "Bache, M. D. Member of the American Philosophical Society, and of the Academy "of Natural Sciences of Philadelphia. In two Volumes."

In conformity to the act of the Congress of the United States, entitled "An Act for the Encouragement of Learning, by securing the copies of Maps, Charts, and Books, to the authors and proprietors of such copies, during the times therein mentioned."—And also to the act, entitled, "An act supplementary to an act, entitled, 'An act for the Encouragement of Learning, by securing the copies of Maps, Charts, and Books, to the authors and proprietors of such copies during the times therein mentioned,' and extending the benefits thereof to the arts of designing, engraving, and etching historical and other prints."

D. CALDWELL,
Clerk of the Eastern District of Pennsylvania.

Paper, manufactured by
Joshua and Thomas Gilpin.

C. 11—3—36.

TO

THE RIGHT HONOURABLE

THE EARL OF GLASGOW,

BARON ROSS OF HAWHEAD,

&c. &c. &c.

LORD-LIEUTENANT OF AYRSHIRE.

My Lord,

When I inscribe this volume to your Lordship, it is neither to offer the incense of adulation, which your virtues do not need, and your understanding would disdain; nor to solicit the patronage of exalted rank to a work, which in this age and nation must seek support in scientific value alone. The present dedication is merely an act of gratitude, as pure on my part, as your Lordship's condescension and kindness to me have been generous and unvarying. At my outset in life, your Lordship's distinguished favour cherished those studious pursuits, which have since formed my chief pleasure and business; and to your Lordship's hospitality I owe the elegant retirement, in which many of the following pages were written. Happy would it have been for their readers, could I have transfused into them a portion of that grace of diction, and elevation of sentiment, which I have so often been permitted to admire in your Lordship's family.

I have the honour to be,
My Lord,
Your Lordship's most obedient
And very faithful Servant,
ANDREW URE.

Glasgow, Nov. 7, 1820.

INTRODUCTION.

In this Introduction I shall first present a GENERAL VIEW of the objects of chemistry, along with a scheme for converting the alphabetical arrangement adopted in this volume, into a systematic order of study. I shall then describe the manner in which this Dictionary seems to have been originally compiled, and the circumstances under which its present regeneration has been attempted. This exposition will naturally lead to an account of the principles on which the investigations of chemical theory and facts have been conducted, which distinguish this Work from a mere compilation. Some notice is then given of a treatise on practical chemistry, publicly announced by me upwards of three years ago, and of the peculiar circumstances of my situation, as a teacher, which prompted me to undertake it, though its execution has been delayed by various obstructions.

THE forms of matter are numberless, and subject to incessant change. Amid all this variety which perplexes the common mind, the eye of science discerns a few unchangeable primary bodies, by whose reciprocal actions and combinations, this marvellous diversity and rotation of existence, are produced and maintained. These bodies, having resisted every attempt to resolve them into simpler forms of matter, are called *undecompounded*, and must be regarded in the present state of our knowledge as *experimental elements*. It is possible that the elements of nature are very dissimilar; it is probable that they are altogether unknown; and that they are so recondite, as for ever to elude the sagacity of human research.

The primary substances which can be subjected to measurement and weight, are fifty-three in number. To these, some chemists add the imponderable elements,—light, heat, electricity, and magnetism. But their separate identity is not clearly ascertained.

Of the fifty-three ponderable principles, certainly three, possibly four, require a distinct collocation from the marked peculiarity of their powers and properties. These are named *Chlorine*, *Oxygen*, *Iodine* (and Fluorine?) These bodies display a pre-eminent activity of combination, an intense affinity for most of the other forty-nine bodies, which they corrode, penetrate, and dissolve; or, by uniting with them, so impair their cohesive force, that they become friable, brittle, or soluble in water, however dense, refractory, and insoluble they previously were. Such changes, for example, are effected on platinum, gold, silver, and iron, by the agency of chlorine, oxygen, or iodine. But the characteristic feature of these archeal elements is this, that when a compound consisting of one of them, and one of the other forty-nine more passive elements, is exposed to voltaic electrization, the former is uniformly evolved at the positive or vitreo-electric pole, while the latter appears at the negative or resino-electric pole.

The singular strength of their attractions for the other simple forms of matter, is also manifested by the production of heat and light, or the phenomenon of combustion, at the instant of their mutual combination. But this phenomenon is not characteristic; for it is neither peculiar nor necessary to their action, and, therefore, cannot be made the basis of a logical arrangement. Combustion is vividly displayed in cases where none of these primary dissolvents is concerned. Thus some metals combine with others with such vehemence as to elicit light and heat; and many of them, by their union with sulphur, even *in vacuo*, exhibit intense combustion. Potassium burns distinctly in cyanogen (carburetted azote), and splendidly in sulphuretted hydrogen. For other examples to the same purpose, see COMBUSTIBLE and COMBUSTION.

And again, the phenomenon of flame does not necessarily accompany any of the actions of oxygen, chlorine, and iodine. Its production may be regulated at the pleasure of the chemist, and occurs merely when the mutual combination is rapidly effected. Thus chlorine or oxygen will unite with hydrogen, either silently and darkly, or with fiery explosion, as the operator shall direct.

Since, therefore, the quality of exciting or sustaining combustion is not peculiar to these vitreo-electric elements; since it is not indispensable to their action on other substances, but adventitious and occasional, we perceive the inaccuracy of that classification which sets these three or four bodies apart under the denomination of *supporters of combustion;* as if, forsooth, combustion could not be supported without them, and as if the support of combustion was their indefeisible attribute, the essential concomitant of their action. On the contrary, every change which they can produce, by their union with other elementary matter, may be effected *without* the phenomenon of combustion. See section 5th of article COMBUSTION.

The other forty-nine elementary bodies have, with the exception of azote (the solitary incombustible), been grouped under the generic name of *combustibles*. But in reality combustion is independent of the agency of all these bodies, and therefore *combustion may be produced without any combustible*. Can this absurdity form a basis of chemical classification? The decomposition of euchlorine, as well as of the chloride and iodide of azote, is accompanied with a tremendous energy of heat and light; yet no combustible is present. The same examples are fatal to the theoretical part of Black's celebrated doctrine of latent heat. His facts are, however, invaluable, and not to be controverted, though the hypothetical thread used to connect them be finally severed.

To the term *combustible* is naturally attached the idea of the body so named affording the heat and light. Of this position, it has been often remarked, that we have no evidence whatever. We know, on the other hand, that oxygen, the incombustible, could yield, from its latent stores, in Black's language, both the light and heat displayed in combustion; for mere mechanical condensation of that gas, in a syringe, causes their disengagement. A similar condensation of the combustible hydrogen, occasions, I believe, the evolution of no light. From all these facts, it is plain, that the above distinction is unphilosophical, and must be abandoned. In truth, every insulated or simple body has such an appetency to combine, or is solicited with such attractive energy by other forms of matter, whether the actuating forces be electo-attractive, or electrical, that the motion of the particles constituting the change, if sufficiently rapid, may always produce the phenomenon of combustion.

Of the forty-nine resino-polar elements, forty-three are metallic, and six non-metallic.

The latter group may be arranged into three pairs:—

1st. The gaseous bodies, Hydrogen and Azote;
2d. The fixed and infusible solids, Carbon and Boron;
3d. The fusible and volatile solids, Sulphur and Phosphorus.

The forty-three metallic bodies are distinguishable by their habitudes with oxygen, into two great divisions, the Basifiable and Acidifiable metals. The former are thirty-six in number, the latter seven.

Of the thirty-six metals, which yield by their union with oxygen salifiable bases, three are convertible into alkalies, ten into earths,* and twenty-three into ordinary metallic oxides. Some of the latter, however, by a maximum dose of oxygen, seem to graduate into the acidifiable group, or at least cease to form salifiable bases.

We shall now delineate a general chart of Chemistry, enumerating its various leading objects in a somewhat tabular form, and pointing out their most important relations, so that the readers of this Dictionary may have it in their power to study its contents in a systematic order.

CHEMISTRY

Is the science which treats of the specific differences in the nature of bodies, and the permanent changes of constitution, to which their mutual actions give rise.†

This diversity in the nature of bodies is derived either from the aggregation or composition of their integrant particles. The state of *aggregation* seems to depend on the relation between the cohesive attraction of these integrant particles, and the antagonizing force of heat. Hence, the three general forms of *solid*, *liquid*, and *gaseous*, under one or other of which every species of material being may be classed.

For instruction on these general forms of matter, the student ought to read, 1st, The early part of the article Attraction; 2d, Crystallization; 3d, That part of Caloric entitled, "Of the change of *state* produced in bodies by caloric, independent of change of composition." He may then peruse the introductory part of the article Gas and Balance, and Laboratory. He will now be sufficiently prepared for the study of the rest of the article Caloric, as well as that of its correlative subjects, Temperature, Thermometer, Evaporation, Congelation, Cryometer, Dew, and Climate. The order now prescribed will be found convenient. In the article Caloric, there are a few discussions, which the beginner may perhaps find somewhat difficult. These he may pass over at the first reading, and resume their consideration in the sequel. After Caloric he may peruse Light, and the first three sections of Electricity.

The article Combustion, will be most advantageously examined, after he has become acquainted with some of the diversities of Composition; viz. with the three vitreo-polar dissolvents, oxygen, chlorine, and iodine; and the six non-metallic resino-polar elements, hydrogen, azote, carbon, boron, sulphur, and phosphorus. Let him begin with *oxygen*, and then peruse, for the sake of connexion, *hydrogen*, and *water*. Should he wish to know how the specific gravity of gaseous matter is ascertained, he may consult the fourth section of the article Gas.

The next subject to which he should direct his attention is Chlorine; on which he will meet with ample details in the present Work. This article will bear a second perusal. It describes a series of the most splendid efforts ever made by the sagacity of man, to unfold the mysteries of nature. In connexion with it he may read the articles CHLOROUS and CHLORIC OXIDES, or the protoxide and deutoxide of Chlorine. Let him next study the copious article Iodine, from beginning to end.

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* I here regard silica acting as a base to fluoric acid, in the fluosilicic compound; but the subject is mysterious. See Acid (Fluoric).

† I do not know whether this definition be my own, or borrowed. I find it in the syllabus of my Belfast Lectures, printed many years ago. Another definition has been given in the Dictionary, article Chemistry.

Carbon, boron, sulphur, phosphorus, and azote, must now come under review. Related closely with the first, he will study the *carbonous oxide, carburetted* and *subcarburetted hydrogen*. What is known of the element *boron*, will be speedily learned; and he may then enter on the examination of *sulphur*, *sulphuretted hydrogen*, and *carburet of sulphur*. *Phosphorus* and *phosphuretted hydrogen*, with *nitrogen* or *azote*, and its *oxides* and *chlorides*, will form the conclusion of the first division of chemical study, which relates to the elements of most general interest and activity. The general articles *Combustible*, *Combustion*, and *Safe-lamp* may now be read with advantage; as well as the remainder of the article *attraction*, which treats of affinity.

Since in the present work the *alkaline* and *earthy salts* are annexed to their respective *acids*, it will be proper, before commencing the study of the latter, to become acquainted with the alkaline and earthy bases.

The order of reading may therefore be the following: first, The general article *alkali*, then *potash* and *potassium*, *soda* and *sodium*, *lithia*, and *ammonia*. Next, the general article *earth;* afterwards *calcium* and *lime*, *barium* and *barytes*, *strontia*, *magnesia*, *alumina*, *silica*, *glucina*, *zirconia*, *yttria*, and *thorina*.

Let him now peruse the general articles *acid* and *salt*; and then the *non-metallic* oxygen acids, with their subjoined salts, in the following order:—*sulphuric*, *sulphurous*, *hyposulphurous*, and *hyposulphuric; phosphoric*, *phosphorous* and *hypophosphorous; carbonic* and *chloro-carbonous; boracic;* and lastly, the *nitric* and *nitrous*. The others may be studied conveniently with the hydrogen group. The order of perusing them may be, the *muriatic* (hydrochloric of M. Gay-Lussac), *chloric* and *perchloric*; the *hydriodic*, *iodic* and *chloriodic;* the *fluoric*, *fluoboric*, and *fluosilicic;* the *prussic* (hydrocyanic of M. Gay-Lussac), *ferroprussic*, *chloroprussic*, and *sulphuroprussic*. The *hydrosulphurous* and *hydrotellurous*, are discussed in this Dictionary, under the names of *sulphuretted hydrogen*, and *telluretted hydrogen*. These compound bodies possess acid powers, as well perhaps as arsenuretted hydrogen. It would be advisable to peruse the article *prussine* (*cyanogen*) either before or immediately after *prussic acid*.

As to the vegetable and animal acids, they may be read either in their alphabetical order or in any other which the student or his teacher shall think fit. Thirty-eight of them are enumerated in the sequel of the article ACID; of which two or three are of doubtful identity.

The metallic acids fall naturally under metallic chemistry; on the study of which I have nothing to add to the remarks contained in the general article METAL. Along with each metal in its alphabetical place, its native state, or *ores*, may be studied. See ORES.

The chemistry of organized matter may be methodically studied by perusing, first of all, the article *vegetable kingdom*, with the various products of vegetation there enumerated; and then the article *animal kingdom*, with the subordinate animal products and *adipocere*.

The article *analysis* may be now consulted; then *mineral* WATERS; *equivalents* (*chemical*); and analysis of *ores*.

The mineralogical department should be commenced with the general articles *mineralogy*, and *crystallography;* after which the different species and varieties may be examined under their respective titles. The enumeration of the *genera* of M. Mohs, given in the first article, will guide the student to a considerable extent in their methodical consideration. Belonging to mineralogy, are the subjects, *blow-pipe*, *geology* with its subordinate *rocks*, *ores*, and *meteorolite*.

The medical student may read with advantage, the articles, *acid* (*arsenious*,) *antimony*, *bile*, *blood*, *calculus* (urinary), the sequel of *copper*, *digestion*, *gall-stones*, *galvanism*, *intestinal concretion*, *lead*, *mercury*, *poisons*, *respiration*, *urine*, *&c.*

- The agriculturist will find details not unworthy of his attention, under the articles, *absorbent*, *analysis* of soils, *carbonate*, *lime*, *manure*, and *soils*.

Among the discussions interesting to manufacturers are, *acetic*, and other *acids*, *alcohol*, *alum*, *ammonia*, *beer*, *bleaching*, *bread*, *caloric*, *coal*, and *coal-gas*, *distillation*, *dyeing*, *ether*, *fat*, *fermentation*, *glass*, *ink*, *iron*, *ores*, *potash*, *pottery*, *salt*, *soap*, *soda*, *steel*, *sugar*, *tanning*, *&c.*

The general reader will find, it is hoped, instruction blended with entertainment, in the articles, *aërostation*, *air*, *climate*, *combustion*, *congelation*, *dew*, *electricity*, *equivalents*, *galvanism*, *geology*, *light*, *meteorolite*, *rain*, and several other articles formerly noticed.

It may be proper now to say something concerning the execution of the present Work. In the month of June, a gentleman from London, who had become possessed of the copy-right of Nicholson's Dictionary, waited on me in Glasgow, requesting that I would superintend the revision of a new edition, which he purposed immediately to send to the press. I stated to him, that, however valuable Nicholson's compilation might have been at its appearance in 1808, the science of chemistry had undergone such alterations since, as would require a Dictionary to be written in a great measure anew. To this he replied, that the above work had enjoyed great popularity; that he was certain a new edition of it would be well received; that he did not expect me to compose original articles or dissertations, but merely to add, from recent publications, such notices of new discoveries and improvements as might seem proper, and to retrench what appeared obsolete or useless; taking care to comprise the whole in such a compass as would render the price moderate, and thus place the book within the reach of manufacturers, medical students, and general readers. The terms offered appearing reasonable relative to the work required, I entered into an engagement to revise the new edition in time for the winter classes.

Having assembled complete series of all the British scientific journals, with several of the foreign, and the various chemical compilations from Newman and Macquer, to the present day, I commenced the stipulated revision. I had advanced a very little way, however, when I became alarmed at the dilemna in which I found myself placed. A large proportion of the articles which I had reckoned on reprinting, as having undergone little change since 1808, were found to have been quite obsolete at that period. They had been evidently copied, with scarcely any alteration, through Nicholson's quarto Dictionary, from Macquer and Newman, back I believe to the era of Stahl, Becher, and Agricola. Under the article *acid* (*acetic*), 36 pages of Crell's Annals had been copied *verbatim et seriatim* on the concentration of vinegar by charcoal, &c. A larger space was allotted to the separation of silver, under the articles *silver*, *parting*, and *assay*, than was dedicated to all the gases and earths. The article Caloric was meagre and vapid, while *desulphuration* or roasting of pyrites, Brazil wood, and safflower, occupied a far greater extent. Putrefaction consisted of extracts from Becher's subterranean world, and other details belonging to a former age of chemistry.

The contents of the 8vo Dictionary were made up from four sources.

1st, From his quarto Dictionary of 1795. The long article *Ores*, for example, was taken chiefly from Cramer, while the labours of Klaproth and Vauquelin were seldom noticed. Large excerpts were also given from obsolete Dispensatories, concerning substances of no chemical importance, and destitute of all medicinal power.

2d, From the contemporary systems of Brongniart, Henry, Murray, Thomson, &c. about another fourth was copied in continuous articles. This formed the best part of the whole.

3d, Large excerpts were given from his own Journal, quite disproportionate to the rest of the work, and to the exclusion of numerous interesting topics. Indeed a journalist, who compiles a system, has great temptations to fall into this practice.

4th, The fourth portion was composed by himself. This seems to have constituted about one-twentieth of the Dictionary, and related chiefly to physics, in which he was experimentally versant. These articles were very respectable, and have been in some measure retained; see *Attraction*, *Balance*, *Hydrometer*, and *Laboratory*. What follows the first asterisk in Attraction, has been now added. Mr. Nicholson was indeed a man of candour, intelligence, and ingenuity. His original papers on electricity, and mechanical science, do him much honour; and the abstracts of experimental chemical memoirs, which he occasionally drew up for his Journal, were ably executed. Had he bestowed corresponding pains on his 8vo Dictionary, my present task would have been greatly lighter.

After making such a survey, the feelings under which I began to labour were similar to those of an architect, who having undertaken to repair a building within a certain period, by replacing a few unsightly or mouldering stones, finds himself, on his first operations, overwhelmed in its rubbish. Reverence to public opinion, and anxiety to fulfil my engagement, however irksome, have induced me to make every possible exertion to restore the edifice, and renew the decayed parts with solid materials. If it has not all the symmetry, or compactness, of an original design, leisurely executed, still I trust it will prove not altogether unworthy the attention of the chemical world. I have investigated the foundation of almost every fact or statement which it contains, and believe they merit general confidence. Many inaccurate positions and deductions, in our most elaborate modern system, I have taken the liberty of pointing out; aware that the influence of Dr. Thomson's name and manner is capable of giving considerable currency to his opinions, however erroneous they may be. His industry deserves the highest praise; and his chemical experience would entitle his decisions to deference, were they less precipitate, and less dogmatical. Many of my embarrassments in compiling the present volume, have arisen from his contradictory judgments, pronounced in the Annals of Philosophy; see ACIDS PHOSPHORIC, PRUSSIC, &c. If under the influence of the feelings thus excited, a hasty expression has escaped me in the ardour of composition, I hope it will not be imputed to personal animosity. I have always lived on amicable terms with this distinguished chemist, and trust to continue so to do. Perhaps in commenting on his opinions, I may have unconsciously caught the plain manner of his criticisms. My sole object, however, was the establishment of truth. The refutation of error was undertaken, only when its existence seemed incompatible with that object. On our other valuable systematic works, I have made no critique, because Dr. Thomson's is the most comprehensive, professedly taken from original memoirs, and of highest authority.

I have long meditated to publish a methodical treatise on chemistry, in which both its study and practice would be greatly simplified, and its applications to the phenomena of nature, medicine, and the arts, faithfully detailed. In my memoir on sulphuric acid, inserted in the Journal of Science and the Arts, for October 1817, is the following passage: "I was led to examine the subject very minutely, in preparing for publication a general system of chemical instructions, to enable apothecaries, manufacturing chemists, and dealers, to practise analysis with accuracy and despatch, as far as their respective arts and callings require. I hope that this work will soon appear. Meanwhile, the following details will afford a specimen of the experimental researches executed with this view." The three years and a half which have elapsed since the above paper was composed, would have enabled me to fulfil the promise, but for various unforeseen interruptions to my labours.

If the public, after this larger specimen of my chemical studies, shall deem me qualified for the task, I may promise its completion within a year from this date. The work will be comprised in four octavo volumes, and will contain the results of numerous investigations into the various objects of practical chemistry, joined to a systematic view of its principles. By several simple instruments, tables, and rules of calculation, chemical analysis, the highest and most intricate part of the science, may, I apprehend, be, in many cases, brought within the reach of the busy manufacturer; while, by the same means, such accuracy and despatch may be insured, as to render the analysis of saline mixtures, complex minerals, and mineral waters, the work of an hour or two; the proportions of the constituents being determined to one part in the thousand.

In prosecution of this plan of simplifying analysis, I contrived, about five years ago, an alkalimeter and acidimeter. Being then connected by a biennial engagement with the Belfast Academical Institution, I was occasionally called upon to examine the barillas and potashes so extensively employed in the linen manufacture, the staple trade of Ireland. I was sorry to observe, that while these materials of bleaching differed excessively in their qualities, no means was possessed by those who imported or who used them, of ascertaining their value; and that a generous people, with whom every stranger becomes a friend, frequently paid an exorbitant price for adulterated articles. The method which I devised for analyzing alkaline and acid matter, was laid before the Honourable Linen Board in Dublin, and by them referred to a competent chemical tribunal. The most decisive testimonies of its accuracy and importance were given by that tribunal; and it was finally submitted, by desire of the Board, to a public meeting of bleachers assembled at Belfast. Unexceptionable documents of its practicability and value were thence returned to Dublin, accompanied by an official request, that measures might immediately be taken to introduce the method into general use. Descroizilles had several years before described, in the Annales de Chimie, an alkalimeter, but so clumsy, operose, and indirect, as to be not at all adapted to the purposes of the linen manufacture. My instrument, indeed, was founded, as well as his, on the old principle of neutralizing alkali with acid; but in every other respect it was different.

After spending about two months on this project, and no answer being returned either to the public request of the bleachers, or to my own memorial, I set off on an intended tour to France, and have never since resumed the negotiation.* The terms on which I had offered the instrument, were merely honorary; for the sum proposed, would not have repaid the expense of my journey and attendance. However important therefore the adoption of that instrument was to Ireland, it was of no pecuniary importance whatever to me. Of the two hundred and ten thousand pounds expended that year (1815-1816) on imported alkalies, a very large proportion might have been saved by the application of my alkalimeter; and what is perhaps of more consequence, the alkaline leys used in bleaching, would, by its means, have been rendered of a regulated strength, suited to the stage of the process, and fabric of the cloth. What would we say of a company, who imported spirituous liquors to an enormous amount, and paid for them all as proof, though they were diluted with fifty per cent. of water? Now, though this neglect of the hydrometer would have a happy moral influence on the consumer, it would be vastly absurd in the dealer. No such apology can be offered for neglecting the alkalimeter.

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* The Right Hon. John Foster, who took the chief direction of the Board, showed me every possible attention; but from the absence of many of its members in England, a quorum could not be assembled at the time.

The following is an extract from the Belfast News-Letter of July 9, 1816:—

"I now submit the following document to public inspection, and humbly ask, whether any such experiment has been ever made publicly before; or whether there is described in any publication prior to my late exhibition in Dublin, and in the Linen Hall of Belfast, an instrument by which it can be performed?

"This day, one of the porters of the Linen Hall, Belfast, was called into the Library-room, at the request of Dr. Ure, who, being quite unknown to Dr. Ure, and never having seen any experiments made with acids and alkalies, he took the instrument at our desire, which, being filled with coloured acid, by pouring it slowly on adulterated alkali, which we had previously prepared, he ascertained exactly the per centage of genuine alkali in the mixture.—*Belfast*, *25th June*, 1816.

(Signed) John S. Ferguson, *Chairman.*
James M'Donnel, *M. D.*
John M. Stoupe,
S. Thomson, *M. D.*

"The above experiment did not occupy the porter above five minutes. I believe it is a new document, though, after the egg has been placed on end, others will set to work to do the same.

"Though the instrument was entirely the result of my own experiments and calculations, I never claimed a greater share in its invention, than I hope its peculiarity merits. The following excerpt from a letter addressed to the Right Hon. John Foster, *prior* to any public discussion on its merits, will satisfy the public on this head.

"*Dublin*, *June* 12, 1816.

"Sir,—In the letter which I had yesterday the honour of addressing you, I omitted some scientific details, which I now beg leave to submit to your consideration. That the quantity of alkali, present in any portion of potash or barilla, is directly proportional to the quantity of acid requisite to produce saturation, is a fact which has been known for upwards of a century to every chemist, and forms a fundamental law of his science. In establishing my instrument on this law, the principle of it may be said not to be new." &c.

"The practical application of the established laws of nature, or of the general deductions of science, to the uses of life, is, perhaps, the most beneficial and meritorious employment of the philosophic mind. The novelty which I lay claim to in my contrivance, is this, that it enables a person versant neither in *chemical researches* nor in *arithmetical computation*, to determine by inspection of a scale, as simple as that of a thermometer, the purity or value to one part in the hundred, of the alkalies, oil of vitriol, and oxymuriate of lime, so extensively, and often so injudiciously employed by the linen-bleacher."

In my journey through England to France, I submitted my Essay on Alkalimetry, &c. to Dr. Henry, in the confidence of friendship, and under the injunction of secrecy. From the unreserved communication of ideas, however, which subsists between this chemist and his townsman Mr. Dalton, he soon gave him a perusal of the Essay. In the then existing edition of Dr. Henry's Elements, Descroizilles' plan for testing alkalies was alone given; in the edition published since, he has inserted four supplementary pages entitled,

"*Improved Alkalimeter and Acidimeter.*"

This instrument is essentially mine, very slightly disguised. He concludes by saying, "No chemical operation can be more simple, or more easily managed, than the measurement of the strength of alkalies by acid liquors, and of acids by alkaline ones, *in the way which has been described.*" This is exactly Columbus's egg, or Roger Bacon's gunpowder; *et sic facies tonitru*, SI SCIAS ARTIFICIUM. By comparing his new way taken from my Essay, with the methods which he formerly gave, the world will see whence the simplification originated. I offered to give him an abridged account of my plan, for insertion in his Elements, after my negotiation about the alkalimeter was finished. Without consulting me on the subject, he publishes to the whole world, what he conceives to be the essence of my improvement.*

Two motives have hitherto withheld me from laying the instrument before the public. First, a desire to render it as complete as possible; and secondly, an expectation, that the Honourable Board, who superintend the linen manufactures of Ireland with extensive powers, might wish that an instrument originally presented to them, and which is capable of giving light and precision to all the processes of bleaching, should appear under their auspices.

As it now exists, the instrument is greatly superior to that described by Dr. Henry. For the commercial alkalies and acids, I use only two test liquids and one scale; and these are such, that a man unacquainted with science, may prepare the first, and verify the second. The instrument is at once an alkalimeter, an acidimeter, a complete lactometer, a nitrometer for estimating the value of nitre, an indigometer for ascertaining the dyeing quality of indigo, and a blanchimeter for measuring the bleaching power of oxymuriate (chloride) of lime and potash. With it, a busy manufacturer or illiterate workman may solve all these useful problems in a few minutes; and many others, such as the composition of alloys of silver, of copper, tin, lead, &c. the purity of white lead, and other pigments. It is, moreover, a convenient hydrometer, comprehending in its range, light and heavy liquids, from ether to oil of vitriol; and is particularly adapted to take the specific gravity of soils.

It may be said, that the solution of the above problems may be accomplished by any skilful chemist. But surely, in a manufacturing nation, the person who brings the science of Klaproth, Sir H. Davy, Dr. Wollaston, and M. Gay-Lussac, into the workshop of the manufacturer, is not a useless member of the community.

The result of numerous researches made with that view, has shown me the possibility of rendering analysis in general, a much easier, quicker, and more certain operation, than it seems hitherto to have been, in ordinary hands. To these practical applications of science, my attention has been particularly directed, in conducting that department of Anderson's Institution, destined to diffuse among the manufacturers and mechanics of Glasgow and its neighbourhood, a knowledge of the scientific principles of their respective arts. In a public address, delivered to the members of this class, on a gratifying occasion in April 1816, I remarked, "That Europe affords no similar example of a class, composed of several hundred artisans, mechanicians, and engineers, weekly assembled,[*] with exemplary decorum, to study the scientific principles of the useful arts; to have the great practical truths of philosophy, first revealed by Newton and Lavoisier, made level to their various capacities by familiar descriptions, models, and experiments. The original design of the mechanic's class was limited, as you know, to the exhibition and explanation of mechanical models. But a subject deserving particular attention, was that of the chemical arts, in which many of you are engaged; a knowledge of the scientific principles of which, as taught in the Colleges, circumstances permit few of you to acquire. You have listened to my chemical lessons with the keenest interest; and have applied your studies to conspicuous advantage. Need I adduce, among other things, the unrivalled beauty of the Adrianople madder dye, as executed on the most extensive scale,[†] by individuals who have been my faithful pupils, for nearly the whole course of my public career. By a steady prosecution of this expanded system of instruction, your class has progressively increased in number and importance; so that, within the last twelve years, I have delivered twenty-one courses of lectures to upwards of six thousand students in this department alone."

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* It would seem that Dr. Ure has since been satisfied that Dr. Henry intended him no injustice, as this gentleman has explained to him, that in a passage of his Elements, "page 512, vol. ii. he intended to give Dr. Ure the credit of inventing an instrument on the principle of directly, and without calculation, indicating the per centage of alkali in any specimen, and that he pretended to nothing more than a modification of Dr. Ure's method." See Letter of Dr. Ure, in the Journal of Science, No. 22, p. 401, July, 1820.—*American Editor.*

It is much to be desired, that similar courses of prelections were instituted in all the large towns of the British empire. The deportment of the mechanic's class, amounting occasionally to five hundred members, might serve as a pattern to more dignified assemblies. I have never seen any University class so silent and attentive. Though the evening on which the workmen meet, be that in which they receive their wages, and when, therefore, they might be expected to indulge themselves in drinking, yet no instance of intemperance has ever occurred to annoy the audience. And even during the alarms of insurrection with which our city was disturbed last winter, the artisans continued with unaltered docility and punctuality to frequent the lectures.

Of the actual result of such a system of instruction, a stranger is probably the best judge. I shall therefore quote a few sentences from the Scientific Tour through Great Britain, recently published by an accomplished member of the Institute of France, M. Ch. Dupin.

"It is easier to visit the establishments and manufactures of Glasgow, than those of any other city in the British empire. The liberal spirit of the inhabitants, is, in this respect, carried as far as possible, among a manufacturing people, who must naturally dread, and seek to prevent, not only the loss of their preponderance, but their foreign rivalry.

"The rich inhabitants of Glasgow have founded the Andersonian Institution, where are taught, in the evenings of winter, the elements of mechanics, physics, and chemistry, as applied to the arts. These courses are especially designed for young artisans, who have to pay only about five shillings in the season (course of three months.)

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[*] Every Saturday evening at eight o'clock.

[†] Particularly at the establishment of H. Monteith, Esq. M. P. where the sciences of mechanics and chemistry co-operate, in a degree of precision and elegance, which I believe to be unparalleled in the world.

"This trifling fee is exacted, in order that the class may include only students actuated by the love of instruction, and willing to make some small sacrifice for it.

"The Andersonian Institution has produced astonishing effects. It is an admirable thing now, to see in many Glasgow manufactories, simple workmen, who understand, and explain when necessary, the principles of their operations, and the theoretical means of arriving at the most perfect possible practical results."

The philanthropist may perhaps wish to know, at what expense of patronage this useful department is carried on. I shall satisfy this desire, by the following statement from the above mentioned public address.

"The original design of the mechanic's class was limited, as you know, to the exhibition and explanation of mechanical models. But the progress of machinery in your workshops, has now so far outrun the state of the models left by the venerable Founder of the Institution, as to render their display, with a very few exceptions, useless, except as historical documents of the rudeness of the times in which they were framed. I have, accordingly, for ten years, employed chiefly modern apparatus, procured at my own expense, and by rendering the instructions miscellaneous, have adapted them better to the diversity of your pursuits. Besides teaching the usual elements of mechanics and their general combinations, I have made it my business to explain the properties of the atmosphere, on which the action of pumps depends; the nature of hydrostatic equilibrium, and hydraulic impulse, as subservient to the construction of Bramah's press, and water-wheels; the beautiful laws of heat so admirably applied to perfect the steam-engine, by our illustrious fellow-citizen; nor have I declined, in compliance with your wishes, to lay before you from time to time, such views of the constitution of nature, in electricity, optics, and astronomy, as might awaken the powers of your minds, and reward your attention to the less attractive branches of science. But a subject, deserving particular attention, was that of the chemical arts," &c. (as above quoted.)

The whole experimental means at present employed in carrying on this POLYTECHNIC SCHOOL, have been derived from the exertions and sacrifices of the Professor, and the generous aid and contributions of his pupils. They have supplied him with much valuable practical information on their respective arts, with many curious models, and subsidiary instruments of illustration; while he, in return, has expended large sums of money, in framing popular representations of the scientific discoveries and improvements, in which the present age is so prolific.

To the mechanic's class a library is attached, consisting of the best treatises on the sciences and arts, with some valuable works on general literature, such as history, geography, travels, &c. of which they have the exclusive management and perusal. The foundation of it was laid in the year 1807, by a voluntary subscription, amounting, I think, to about 60*l*.; and several books which I collected from my friends, with about 100 volumes from my own library. Many members of the class have contributed from time to time; and it has recently acquired considerable extension, from the receipts of lectures which I delivered for its benefit.

Besides the acknowledged and palpable effect of such a plan of tuition, on the improvement of the useful arts, it has another operation, more silent, but neither less certain, nor less important, namely, its influence in meliorating the moral condition of the operative order of society.

A taste for science elevates the character, and creates a disrelish, and disgust, at the debasement of intoxication. Philosophy dressed in an attractive garb, leads away from the temptations of the tavern. Thus, too, the transition from the drudgery or turmoil of the week, to the tranquillity of Sunday, is secured by the preceding evening's occupation. The man indeed whose Saturday night is spent in rioting or drunkenness, will make a bad Christian on the Sabbath, an indifferent workman on Monday, and an unhappy husband and father through the week. To promote this moral operation of science, I have always taken occasion to point out the beneficent design which the whole mechanism of nature displays. If the contemplation of the miseries and crimes which stain the page of history, have led some speculators to cavil at the government of a benevolent Creator; the contemplation of the harmonious laws, and benignant adjustments which the science of nature discloses, must satisfy every candid student, of the presence and providence of a wise and beneficent Lawgiver. The first and most exalted function of physics, then, is to dissipate the gloomy and bewildering mists of metaphysics. A second function of supreme importance, is to point out the mysterious and impassable barriers, to which the clearest paths of physical demonstration ultimately lead the human mind; and thence to inculcate docility to the analogous mysteries of Revelation.

I hope that the preceding statements and remarks, will remove every possible objection to the establishment of schools for teaching the elements of science to artisans, and that they will induce other cities to follow the example so happily set by Glasgow, of popularizing philosophy.

Having detailed the circumstances under which I have struggled to regenerate this Dictionary, I hope the candid Public will make allowance for occasional faults of expression and arrangement. All the articles to which the asterisks are affixed, were, with trifling exceptions, printed from my manuscript, written expressly for this work, within the last five months. From the style of its typography, and the manner of stating proportions of constituents, each page of this volume is fully equivalent to two pages of our octavo systems of chemistry, and required rather more than four pages of closely written manuscript. There is however a great advantage to the reader of a scientific work, (which must necessarily be compiled from many quarters), in an author being his own amanuensis. Every fact and detail will thus be exposed to a much severer scrutiny, than if excerpts were made by the scissars, or the pen of an assistant. Hence many of the passages which may seem, at first sight, to be merely copied from other works, will be found to have corrections and remarks either interwoven with the details, or enclosed in parentheses. Thus, for example, in transcribing Mr. Hatchett's admirable analyses of the magnetic iron ores, computation will be found within parentheses, deduced from Dr. Wollaston's equivalent scale. Numerous insertions and corrections are made in the reprinted parts to which no asterisk is affixed. M. Vauquelin's general mode of analyzing minerals is now introduced, Professor Gahn's instructions relative to the blow-pipe, a long passage under *Arsenious Acid*, and many other unnoted insertions, such as *Chlorophyle*, *Cholesterine*, *Comptonite*.

The dissertations on *Caloric*, *Combustion*, *Dew*, *Distillation*, *Electricity*, *Gas*, *Light*, *Thermometer*, *&c.* which form a large proportion of the volume, are beyond the letter and spirit of my engagement with the publisher. I receive no remuneration for them, not even at the most moderate rate of literary labour. They are therefore voluntary contributions to the chemical student, and have been substituted for what I deemed frivolous and uninteresting details on some unimportant dye-stuffs, and articles from old dispensatories, such as althea, chamomile, &c.

For whatever is valuable in the mineralogical department, the reader is ultimately indebted to Professor Jameson. The chief part of the descriptions of mineral species, is abridged from the third edition of his excellent System. In compiling the early part of the Dictionary, I collated several mineralogical works, both British and foreign; but I soon found that this had been done to my hand by Professor Jameson, with much greater ability than I could pretend to rival; and that he had enriched the whole with many important remarks of his own.

Much of the purely chemical part is drawn from that treasure of facts, Sir H. Davy's elements. When the subject permitted me, I was happy to repose on his never-failing precision, like the wave-tossed mariner in a secure haven. With regard to the language used by him, Dr. Wollaston, M. Gay-Lussac, and some other original investigators, I have used no further freedom than was necessary to accommodate it to the context. Their expressions can very seldom be changed with impunity. There are other chemical writers again, whose thoughts acquire intellectual spring only by great condensation. If the curious reader compare the article DISTILLATION, in this Dictionary, with that in the Supplement to the Encyclopædia Britannica, he will understand my meaning.

In the discussion on the Atomic Theory of Chemistry, under the article EQUIVALENTS, reference is made to a table of the relative weights of the atoms, or of the numbers representing the *prime* equivalents of chemical bodies. On subsequent consideration, it was perceived, that such a list would be merely a repetition of numbers already given in their alphabetical places, and therefore most readily found; whilst it would have caused the omission of requisite tables of a different kind; the space allotted to the volume being entirely occupied.

In my paper on Sulphuric Acid, published in the 7th number of the Journal of Science, I assigned the numbers 4, 5, 6, as respectively denoting the prime equivalents of soda, sulphuric acid, and potash. Minute researches, subsequently made, on the nitrates, (Journal of Science, No. xii.) led me to regard 3.96, and 5.96, as better approximations for soda and potash. Throughout this Dictionary, the numbers 3.95 and 5.95 have been used. It is, however, very possible that the number 6, originally assigned by Sir H. Davy for potash, may be correct; as also 4 for soda.

Dr. Thomson has just published a paper in his Annals, (November 1820) "On the true weight of the atoms of barytes, potash, soda," &c. In his experiments to determine these fundamental quantities, he has adopted Richter's original plan of reciprocal saturation of two neutro-saline compounds. But the Doctor seems to have forgotten, that for want of an initial experiment, none of his ratios is referable to the oxygen scale, or to any atomic radix. He *assumes* the atom of barytes to be 9.75, and that of potash to be 6; that of sulphuric acid being 5. He then proceeds to show that the atomic weight 13.25 of dry muriate of barytes (chloride of barium), and 11, that of sulphate of potash, produce perfect reciprocal decomposition, when their aqueous solutions are mixed. But had he called the atom of barytes 9.7, with Sir H. Davy and Dr. Wollaston, (the chloride would become 13.2), and the atom of sulphate of potash 10.96, as found in my experiments on nitric acid, he would have obtained, by mixing the two, in these atomic proportions, as perfect an experimental result as with his own numbers: For 13.25 : 11 : : 13.2 : 10.96.

His atomic chain wants, in fact, its first link; it floats loosely; and may therefore be accommodated to a variety of different numbers, provided the arithmetical proportions be observed. He ought to have commenced with a clear demonstration, that the atom of barytes is 9.75, and the atom of potash 6, referred to oxygen as unity.

The idea, however, suggested by Dr. Prout, that the numbers representing the weights of the different atoms, are multiples by a *whole* number of that denoting hydrogen, is very ingenious, and most probably just. And therefore, as well as for experimental reasons, which I cannot here detail, I would willingly adopt 9.75 for barytes, 4 for soda, 6 for potash, and 4.5 for chlorine. The atomic numbers given in this volume, for the various simple and compound objects of chemistry, are directly deduced from a mean of the most exact experiments; and I believe them to be more worthy of confidence, than those deducible from theoretic considerations. Thus, Dr. Thomson, from these, assigns 3.625 for the atom of lime; from experiment, it is certainly not so high. I have stated it from my own, at 3.56. Dr. Marcet's analysis of the carbonate would make it about 3.5. In the article EQUIVALENTS (CHEMICAL), as well as under the individual substances, the reader will find the primitive combining ratios, or atoms as they are hypothetically called, fully, and I trust fairly, investigated from experiment. This is the sheet-anchor of scientific research, which we must never part with, or we shall drift into interminable intricacies. We should continually bear in mind this aphorism of the master of chemical Logic: "The substitution of analogy for fact is the bane of chemical philosophy; the legitimate use of analogy is to connect facts together, and to guide to new experiments."—*Sir H. Davy, Journal of Science*, vol. i.

These analogical substitutions appear to be the predominant defect of Dr. Thomson's otherwise valuable compilation.

The typographical economy of this work precluded me from multiplying references at the bottom of the page; a plan which authors readily adopt to show the extent of their reading. The authorities for facts will be generally found interwoven with the text. The desire to condense much practical information, in a small compass, made me abridge many historical details. The progressive steps of an investigation, however, occasionally required to be traced, in order to make the existing state of our knowledge more intelligible. Whenever this seemed necessary, I have offered such a retrospect, and have endeavoured to take truth and justice for my sole guides. As the only recompense which the man of science usually receives or can expect, is the credit of his discoveries, neither prejudice nor passion should be suffered to influence the compiler, in awarding honour to whom honour is due.

One of the most elegant investigations which the Science of Chemistry affords, is contained in M. Gay-Lussac's short letter to M. Clement, published in the Annales de Chimie et de Physique for July 1815, and reprinted in 1816, by M. Thenard in his valuable Traité de Chimie, iv. p. 238. It is there demonstrated that sulphuric ether is composed of

2 volumes olefiant gas,
1 volume vapour of water,

condensed into one volume; or by weight in M. Gay-Lussac's numbers, of

0.978 × 2 = 1.956 olefiant gas, and
0.625 × 1 = 0.625 vapour of water.

2.581 sum = theoretic density of vapour,

which differs from 2.586, the experimental density of ether vapour by only $\frac{5}{1000}$ parts. This fine coincidence is fully developed by the French chemist. Now Dr. Thomson was obviously familiar with that paper, for he copies a good part of it, (though without acknowledgment), on the constitution of alcohol, into his articles Brewing and Distillation, *Supplement to Encyclopædia Britan.*, as well as into his System published in October 1817, vol. iv. p. 385. See FERMENTATION in this Dictionary.

I was therefore equally surprised and amused at the following claim, recently set up by him to M. Gay-Lussac's incontestable discovery.

" The experiments which Mr. Dalton has made on the analysis of ether, show in a very satisfactory manner, that the *notion which I threw out* in my System of Chemistry, that sulphuric ether is a compound of two atoms olefiant gas, and one atom vapour of water condensed into one volume, is the true one." " Hence 2 volumes olefiant gas weigh 1.9416

1 volume vapour of water	0.6250
Total	2.5666

Specific gravity of ether vapour 2.5860."—*Annals of Philosophy, August* 1820, p. 81. *Historical Sketch, &c. by Thomas Thomson, M. D. &c.*

Now, though in that Sketch the Dr. seems to show, that Mr. Dalton was unacquainted with M. Gay-Lussac's researches on ether, it was a rather rash presumption to extend that analogy of ignorance to all other British Chemists. The first of the Doctor's periods, quoted above, is nonsense, from his use of the favourite word *atom*, instead of *volume*. The statement in the second is taken from M. Gay-Lussac, and bears the elegant impression of its author.

Glasgow, Nov. 7, 1820.

N. B.—The Articles with the asterisk(*), are inserted by Dr. Ure; the others, with the exceptions noticed in the Introduction, are reprinted from Nicholson's Octavo Dictionary.

PREFATORY REMARKS, BY DR. HARE.

Being requested by the publisher to make any additions or corrections in this American edition of Ure's Nicholson's Dictionary, which might to me appear proper, I have complied as far the allotted time would permit. This, however, was so short, that I have only been enabled to write on some of the topics, concerning which my practical experience, and peculiar and mature reflections, have qualified me to comment advantageously.

The passages added by me will be distinguished by a cross (†), as those by Dr. Ure are by an asterisk.

After the above was written, pursuant to my advice, the publisher engaged Dr. Franklin Bache to revise the work, and read the proofs. I feel it due to Dr. Bache to state, that I am under the impression that he has performed his office with zeal and ability; and that I conceive the work will be much indebted to him for its typographical correctness. His scientific knowledge has enabled him, not only to prevent various new errors, but to correct many previously existing in the original English copy.

A

DICTIONARY

OF

CHEMISTRY.

* **ABSORBENT.** An epithet introduced into chemistry by the physicians, to designate such earthy substances, as seemed to check diarrhœa, by the mere absorption of the redundant liquids. In this sense it is obsolete and unfounded. Professor Leslie has shown that the faculty of withdrawing moisture from the air, is not confined to substances which unite with water in every proportion, as the strong acids, dry alkalis, alkaline earths, and deliquescent salts; but is possessed by insoluble and apparently inert bodies, in various degrees of force. Hence the term Absorbent merits a place in chemical nomenclature.

The substance whose absorbent power is to be examined, after thorough desiccation before a fire, is to be immediately transferred into a phial, furnished with a well ground stopper. When it is cooled, a portion of it is transferred into a large wide-mouthed bottle, where it is to be closely confined for some time. A delicate hygrometer being then introduced, indicates on its scale the dryness produced in the inclosed air, which should have been previously brought to the point of extreme humidity, by suspending a moistened rag within the bottle. The following table exhibits the results of his experiments:—

Alumina causes a dryness of	84	degrees.
Carbonate of magnesia . . .	75	
Carbonate of lime	70	
Silica	40	
Carbonate of barytes	32	
Carbonate of strontites	23	
Pipe clay	85	
Greenstone, or trap in powder	80	
Shelly sea sand	70	degrees.
Clay indurated by torrefaction	35	
Ditto strongly ignited	8	
Greenstone ignited	23	
Quartz do.	19	
Decomposed greenstone . . .	86	
Greenstone resolved into soil	92	
Garden mould	95	

The more a soil is comminuted by labour and vegetation, the greater is its absorbent power. This ingenious philosopher infers, that the fertility of soils depends chiefly on their disposition to imbibe moisture; and illustrates this idea by recent and by disintegrated lava. May not the finely divided state most penetrable by the delicate fibres of plants, derive its superior power of acting on atmospherical vapour from the augmentation of its surface, or the multiplication of the points of contact?

In similar circumstances 100 gr. of the following organic substances absorb the following quantities of moisture: Ivory 7 gr. boxwood 14, down 16, wool 18, beech 28. —*Leslie on Heat and Moisture.**

ABSORPTION. By this term chemists understand the conversion of a gaseous fluid into a liquid or solid, on being united with some other substance. It differs from condensation in this being the effect of mechanical pressure, or the abstraction of caloric. Thus, if muriatic acid gas be introduced into water, it is absorbed, and muriatic acid is formed; if carbonic acid gas and ammoniacal gas be brought into contact, absorption takes place, and solid carbonate of ammonia is produced by the union of their ponderable bases.

There is a case of condensation, which has sometimes no doubt been mistaken for absorption, though none has taken place. When an inverted jar containing a gas confined by quicksilver is removed into a trough of water, the quicksilver runs out, and is replaced by water. But as the specific gravity of water is so much inferior to that of quicksilver, the column of water in the jar resists the atmospheric pressure only with one 14th of the power of the quicksilver, so that the gas occupies less room from being condensed by the increased pressure, not from absorption.

Abstraction. In the process of distillation, the volatile products which come over, and are condensed in the receivers, are sometimes said to be abstracted from the more fixed part which remains behind. This term is chiefly used when an acid or other fluid is repeatedly poured upon any substance in a retort, and distilled off, with a view to change the state or composition of either. See Distillation.

* **Acanticone.** See Pistacite.*

* **Acerates.** The acer compestre, or common maple, yields a milky sweetish sap, containing a salt with basis of lime, possessed, according to Scherer, of peculiar properties. It is white, semi-transparent, not altered by the air, and soluble in nearly 100 parts of cold, or 50 of boiling water.*

* **Aceric Acid.** See Acid (Aceric).*

* **Acescent.** Said of substances which become sour spontaneously, as vegetable and animal juices, or infusions. The suddenness with which this change is effected during a thunder storm, even in corked bottles, has not been accounted for. In morbid states of the stomach, also, it proceeds with astonishing rapidity. It is counteracted by bitters, antacids, and purgatives.*

Acetates. The salts formed by the combination of the acetic acid with alkalis, earths, and metallic oxides. See the different bases.

* **Acetic Acid.** See Acid (Acetic).*

* **Acetometer.** An instrument for estimating the strength of vinegars. It is described under Acid (Acetic).*

Acetous. Of or belonging to vinegar. See Acid (Acetic.)

Achromatic. Telescopes formed of a combination of lenses, which in a great measure correct the optical aberration, arising from the various colours of light, are called achromatic telescopes. Some of these have been made wonderfully perfect, and their excellence appears to be limited only by the imperfections of the art of glass-making. The artifice of this capital invention of Dollond consists in selecting, by trial, two such pieces of glass, to form the object lenses, as separate the variously coloured rays of light to equal angles of divergence, at different angles of refraction of the mean ray; in which case it is evident, that, if they be made to refract towards contrary parts, the whole ray may be caused to deviate from its course without being separated into colours. The difficulty of the glass-maker is in a great measure confined to the problem of making that kind of glass which shall cause a great divergence of the coloured rays with respect to each other, while the mean refraction is small. See Glass; also Aplanatic.

* **Acids.** The most important class of chemical compounds. In the generalization of facts presented by Lavoisier and the associated French chemists, it was the leading doctrine that acids resulted from the union of a peculiar combustible base called the radical, with a common principle technically called oxygen, or the acidifier. This general position was founded chiefly on the phenomena exhibited in the formation and decomposition of sulphuric, carbonic, phosphoric, and nitric acids; and was extended by a plausible analogyto other acids whose radicals were unknown.

"I have already shown," says Lavoisier, "that phosphorus is changed by combustion into an extremely light, white, flaky matter. Its properties are likewise entirely altered by this transformation; from being insoluble in water, it becomes not only soluble, but so greedy of moisture as to attract the humidity of the air with astonishing rapidity. By this means, it is converted into a liquid, considerably more dense, and of more specific gravity than water. In the state of phosphorus before combustion, it had scarcely any sensible taste; by its union with oxygen, it acquires an extremely sharp and sour taste; in a word, from one of the class of combustible bodies, it is changed into an incombustible substance, and becomes one of those bodies called acids.

"This property of a combustible substance, to be converted into an acid by the addition of oxygen, we shall presently find belongs to a great number of bodies. Wherefore strict logic requires that we should adopt a common term for indicating all these operations which produce analogous results. This is the true way to simplify the study of science, as it would be quite impossible to bear all its specific details in the memory if they were not classically arranged. For this reason we shall distinguish the conversion of phosphorus into an acid by its union with oxygen, and in general every combination of oxygen with a combustible substance, by the term *oxygenation*; from this I shall adopt the verb to oxygenate; and of consequence shall say, that in oxygenating phosphorus, we convert it into an acid.

“Sulphur also, in burning, absorbs oxygen gas; the resulting acid is considerably heavier than the sulphur burnt; its weight is equal to the sum of the weights of the sulphur which has been burnt, and of the oxygen absorbed; and, lastly, this acid is weighty, incombustible and miscible with water in all proportions.”

“I might multiply these experiments, and show, by a numerous succession of facts, that all acids are formed by the combustion of certain substances; but I am prevented from doing so in this place by the plan which I have laid down, of proceeding only from facts already ascertained to such as are unknown, and of drawing my examples only from circumstances already explained. In the mean time, however, the examples above cited may suffice for giving a clear and accurate conception of the manner in which acids are formed. By these it may be clearly seen that oxygen is an element common to them all, and which constitutes or produces their acidity; and that they differ from each other according to the several natures of the oxygenated or acidified substances. We must, therefore, in every acid carefully distinguish between the acidifiable base, which M. de Morveau calls the radical, and “the acidifying principle or oxygen.” Elements, p. 115. Although we have not yet been able either to compose or to decompound this acid of sea salt, we cannot have the smallest doubt that it, like all other acids, is composed by the union of oxygen with an acidifiable base. We have, therefore, called this unknown substance the muriatic base, or muriatic radical.” P. 122. 5th Edition.

Berthollet’s sound discrimination led him to maintain that Lavoisier had given too much latitude to the idea of oxygen being the universal acidifying principle. “In fact,” says he, “it is carrying the limits of analogy too far to infer, that all acidity, even that of the muriatic, fluoric, and boracic acids, arises from oxygen, because it gives acidity to a great number of substances. Sulphuretted hydrogen, which really possesses the properties of an acid, proves directly that acidity is not in all cases owing to oxygen. There is no better foundation for concluding that hydrogen is the principle of alkalinity not only in the alkalis, properly so called, but also in magnesia, lime, strontian, and barytes, because ammonia appears to owe its alkalinity to hydrogen.

“These considerations prove that oxygen may be regarded as the most usual principle of acidity, but that this species of affinity for the alkalis may belong to substances which do not contain oxygen; that we must not, therefore, always infer, from the acidity of a substance, that it contains oxygen, although this may be an inducement to suspect its existence in it; still less should we conclude, because a substance contains oxygen, that it must have acid properties; on the contrary, the acidity of an oxygenated substance shows that the oxygen has only experienced an incomplete saturation in it, since its properties remain predominant.”

Amid the just views which pervade the early part of this quotation from Berthollet, it is curious to remark the solecism with which it terminates. For after maintaining that acidity may exist independent of oxygen, and that the presence of oxygen does not necessarily constitute acidity, he concludes by considering acidity as the criterion of unsaturated oxygen.

This unwarrantable generalization of the French chemists concerning oxygen, which had succeeded Stahl’s equally unwarrantable generalization of a common principle of combustibility in all combustible bodies, was first experimentally combated by Sir H. Davy, in a series of admirable dissertations published in the Philosophical Transactions.

His first train of experiments were instituted with the view of operating by voltaic electricity on muriatic and other acids freed from water. Substances which are now known by the names of chlorides of phosphorus and tin, but which he then supposed to contain dry muriatic acid, led him to imagine intimately combined water to be the real acidifying principle, since acid properties were immediately developed in the above substances by the addition of that fluid, though previously they exhibited no acid powers. In July 1810, however, he advanced those celebrated views concerning acidification, which, in the opinion of the best judges, display an unrivalled power of scientific research.—The conclusions to which these led him, were incompatible with the general hypothesis of Lavoisier. He demonstrated that oxymuriatic acid is, as far as our knowledge extends, a *simple* substance, which may be classed in the same order of natural bodies as oxygen gas, being determined like oxygen to the positive surface in voltaic combinations, and like oxygen combining with inflammable substances, producing heat and light. The combinations of oxymuriatic acid with inflammable bodies were shown to be analogous to oxides and acids in their properties and powers of combination, but to differ from them in being for the most part decomposable by water: And finally, that oxymuriatic acid has a stronger attraction for most inflammable bodies than oxygen. His preceding decomposition of the alkalis and earths having evinced the absurdity of that nomenclature, which gives to the general and essential constituent of alkaline nature, the term oxygen or acidifier; his new discovery of the simplicity of oxymuriatic acid, showed the theoretical system of chemical language to be equally vicious in another respect. Hence this philosopher most judiciously discarded the appellation oxymuriatic acid, and introduced in its place the name chlorine, which merely indicates an obvious and permanent character of the substance, its greenish yellow colour. The more recent investigations of chemists on fluoric, hydriodic, and hydrocyanic acids have brought powerful analogies in support of the chloridic theory, by showing that hydrogen alone can convert certain undecompounded bases into acids well characterized, without the aid of oxygen. Dr. Murray indeed has endeavoured to revive and new-model the early opinion of Sir H. Davy, concerning the necessity of the presence of water, or its elements, to the constitution of acids. He conceives that many acids are ternary compounds of a radical with oxygen and hydrogen; but that the two latter ingredients do not necessarily exist in them in the state of water. Oil of vitriol, for instance, in this view, instead of consisting of 81. 5 real acid, and 18. 5 water in 100 parts may be regarded as a compound of 32.6 sulphur + 65.2 oxygen + 2.2 hydrogen. When it is saturated with an alkaline base, and exposed to heat, the hydrogen unites to its equivalent quantity of oxygen, to form water, which evaporates, and the remaining oxygen and the sulphur combine with the base. But when the acid is made to act on a metal, the oxygen partly unites to it, and hydrogen alone escapes.

"Nitric acid, in its highest state of concentration, is not a definite compound of real acid, with about a fourth of its weight of water, but a tenary compound of nitrogen, oxygen, and hydrogen. Phosphoric acid is a triple compound of phosphorus, oxygen, and hydrogen; and phosphorous acid is the proper binary compound of phosphorus and oxygen. The oxalic, tartaric, and other vegetable acids, are admitted to be ternary compounds of carbon, oxygen, and hydrogen; and are therefore in strict conformity to the doctrine now illustrated.

"A relation of the elements of bodies to acidity is thus discovered different from what has hitherto been proposed. When a series of compounds exists, which have certain common characteristic properties, and when these compounds all contain a common element, we conclude, with justice, that these properties are derived more peculiarly from the action of this element. On this ground Lavoisier inferred, by an ample induction, that oxygen is a principle of acidity. Berthollet brought into view the conclusion, that it is not exclusively so, from the examples of prussic acid and sulphuretted hydrogen. In the latter, acidity appeared to be produced by the action of hydrogen. The discovery by Gay-Lussac, of the compound radical cyanogen, and its conversion into prussic acid by the addition of hydrogen, confirmed this conclusion; and the discovery of the relations of iodine still further established it. And now, if the preceding views are just, the system must be still further modified. While each of these conclusions are just to a certain extent, each of them requires to be limited in some of the cases to which they are applied; and while acidity is sometimes exclusively connected with oxygen, sometimes with hydrogen, the principle must also be admitted, that it is more frequently the result of their combined operation.

"There appears even sufficient reason to infer, that, from the united action of these elements, a higher degree of acidity is acquired than from the action of either alone. Sulphur affords a striking example of this. With hydrogen it forms a weak acid. With oxygen it also forms an acid, which, though of superior energy, still does not display much power. With hydrogen and oxygen it seems to receive the acidifying influence of both, and its acidity is proportionally exalted.

"Nitrogen, with hydrogen, forms a compound altogether destitute of acidity, and possessed even of qualities the reverse.—With oxygen, in two definitive proportions, it forms oxides; and it is doubtful if, in any proportion, it can establish with oxygen an insulated acid. But with oxygen and hydrogen in union it forms nitric acid, a compound more permanent, and of energetic action."

It is needless to give at more detail Dr. Murray's speculations, which, supposing them plausible in a theoretical point of view, seem barren in practice; at least their practical tendency cannot be perceived by the editor of this work. It is sufficiently singular, that, in an attempt to avoid the mysterious and violent transformations, which, on the chloridic theory, a little moisture operates on common salt, instantly changing it from chlorine and sodium, into muriatic acid and soda, Dr. Murray should have actually multiplied, with one hand, the very difficulties which he had laboured, with the other, to remove.

He thinks it doubtful if nitrogen and oxygen can alone form an insulated acid.—Hydrogen he conceives essential to its energetic action. What, we may ask then, exists in dry nitre, which contains no hydrogen?† Is it nitric acid, or merely two of its elements, in want of a little water to furnish the requisite hydrogen? The same questions may be asked relative to the sulphate of potash. Since he conceives hydrogen necessary to communicate full force to sulphuric and nitric acids, the moment they lose their water they should lose their saturating power, and become incapable of retaining caustic potash in a neutral state. Out of this dilemma he may indeed try to escape, by saying, that moisture or hydrogen is equally essential to alkaline strength, and that therefore the same desiccation or de-hydrogenation which impairs the acid power, impairs also that of its alkaline antagonist. The result must evidently be, that, in a saline hydrate or solution, we have the reciprocal attractions of a strong acid and alkali, while, in a dry salt, the attractive forces are those of relatively feeble bodies. On this hypothesis, the difference ought to be great between dry and moistened sulphate of potash. Carbonic acid he admits to be destitute of hydrogen; yet its saturating power is very conspicuous in neutralizing dry lime. Now, oxalic acid, by the last analysis of Berzelius, contains no hydrogen. It differs from the carbonic only in the proportion of its two constituents. And oxalic acid is appealed to by Dr. Murray as a proof of the superior acidity bestowed by hydrogen.

On what grounds he decides carbonic to be a feebler acid than oxalic, it is difficult to see. By Berthollet's test of acidity, the former is more energetic than the latter in the proportion of 100 to about 58; for these numbers are inversely as the quantity of each requisite to saturate a given base. If he be inclined to reject this rule, and appeal to the decomposition of the carbonates by oxalic acid, as a criterion of relative acid power, let us adduce his own commentary on the statical affinities of Berthollet, where he ascribes such changes not to a superior attraction in the decomposing substance, but to the elastic tendency of that which is evolved. Ammonia separates magnesia from its muriatic solution at common temperatures; at the boiling heat of water, magnesia separates ammonia. Carbonate of ammonia, at temperatures under 230°, precipitates carbonate of lime from the muriate; at higher temperatures the inverse decomposition takes place with the same ingredients. If the oxalic be a more energetic acid than the carbonic, or rank higher in the scale of acidity, then, on adding to a given weight of liquid muriate of lime, a mixture of oxalate and carbonate of ammonia, each in equivalent quantity to the calcareous salt, oxalate of lime ought alone to be separated. It will be found, on the contrary, by the test of acetic acid, that as much carbonate of lime will precipitate as is sufficient to unsettle these speculations.

Finally, dry nitre, and dry sulphate of potash, are placed, by this supposition, in as mysterious a predicament as dry muriate of soda in the chloridic theory. Deprived of hydrogen, their acid and alkali are enfeebled or totally changed. With a little water both instantly recruit their powers. In a word, the solid sulphuric acid of Nordhausen, and the dry potash of potassium, are alone sufficient to subvert this whole hypothesis of hydrogenation.

We shall introduce, under the head of alkali, some analogous speculations by Dr. Murray on the influence of the elements of water on that class of bodies. *Edin. Phil. Trans. vol. viii. part 2d.*†

After these observations on the nature of acidity, we shall now state the general properties of the acids.

1. The taste of these bodies is for the most part sour, as their name denotes; and in the stronger species it is acrid and corrosive.

2. They generally combine with water in every proportion, with a condensation of volume and evolution of heat.

3. With a few exceptions they are volatilized or decomposed at a moderate heat.

4. They usually change the purple colours of vegetables to a bright red.

5. They unite in definite proportions

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† The acid in dry nitre contains water, and of course hydrogen. Liquid nitric acid is obtained from dry nitre by strong sulphuric acid, and holds, according to the table in this work, under the head of nitric acid, more than a fifth of water.

† I conceive Mr. Murray's views on this subject as nearer the truth than those of the editor. I had adopted conclusions somewhat similar, ere I met with them.

As the characteristic attributes of acidity are never observed in the absence of moisture, water would seem to have higher pretensions to be considered as the acidifying principle than any other *ponderable* substance.

It may be a question, whether acids in a very high state of dephlegmation are really acids or act as such. They do not merely change vegetable blues; they destroy them. They do not produce a sour taste upon the tongue, they cauterize it, and are destructive of, or are destroyed by, substances, which, in a weaker state, they would combine with, so as to yield them up uninjured in obedience to higher affinities.

Concentrated sulphuric acid destroys organic products, by taking up the elements with the alkalis, earths, and metallic oxides, and form the important class of salts. This may be reckoned their characteristic and indispensable property. The powers of the different acids were originally estimated by their relative causticity and sourness, afterwards by the scale of their attractive force towards any particular base, and next by the quantity of the base which they could respectively neutralize. But Berthollet proposed the converse of this last criterion as the measure of their powers. "The power with which they can exercise their acidity," he estimates "by the quantity of each of the acids which is required to produce the same effect, viz. to saturate a given quantity of the same alkali." It is therefore the capacity for saturation of each acid, which, in ascertaining its acidity, according to him, gives the comparative force of the affinity to which it is owing. Hence he infers, that the affinity of the different acids for an alkaline base, is in the inverse ratio of the ponderable quantity of each of them which is necessary to neutralize an equal quantity of the same alkaline base. An acid is, therefore in this view, the more powerful, when an equal weight can saturate a greater quantity of an alkali. Hence, all those substances which can saturate the alkalis, and cause their properties to disappear, ought to be classed among the acids; in like manner, among the alkalis should be placed all those which, by their union, can saturate acidity. And the capacity for saturation being the measure of this property, it should be employed to form a scale of the comparative power of alkalis as well as that of acids.

However plausible, *a priori*, the opinion of this illustrious philosopher may be, that the smaller the quantity of an acid or alkali required to saturate a given quantity of its antagonist principle, the higher should it rank in the scale of power and affinity, it will not, however, accord with chemical phenomena. 100 parts of nitric acid are saturated by about 36½ of magnesia, and by 52½ of lime.

Hence, by Berthollet's rule, the powers of these earths ought to be as the inverse of their quantities, viz. $\frac{1}{36\frac{1}{2}}$ and $\frac{1}{52\frac{1}{2}}$; yet the very opposite effect takes place, for lime separates magnesia from nitric acid. And, in the present example, the difference of effect cannot be imputed to the difference of force with which the substances tend to assume the solid state.

We have therefore at present no single acidifying principle, nor absolute criterion of the scale of power among the different acids: nor is the want of this of great importance. Experiment furnishes us with the order of decomposition of one acido-alkaline compound by another acid, whether alone, or aided by temperature; and this is all which practical chemistry seems to require.

Before entering on the particular acids we shall here describe the general process by which M. Thenard has lately succeeded in communicating to many of them *apparently* a surcharge of oxygen, and thus producing a new class of bodies, the oxygenized acids, which he has had the good fortune of forming and making known to the chemical world. The first notice of these new compounds appeared in the *Ann. de Chimie et Physique, viii.* 306. for July 1818, since which time several additional communications of a very interesting nature have been made by the same celebrated chemist. He has likewise formed a compound of water with oxygen, in which the proportion of the latter principle is doubled, or 616 times its volume is added. The methods of oxygenizing the liquid acids and water, agree in this, that deutoxide of barium is formed first of all, from which the above liquids, by a subsequent process, derive their oxygen. He prescribes the following precautions, without which success will be only partial.

1. Nitrate of barytes should first be obtained perfectly pure, and, above all, free from iron and manganese. The most certain means of procuring it, is to dissolve the nitrate in water, to add to the solution a small excess of barytes water, to filter and crystallize. 2. The pure nitrate is to be decomposed by heat. This ought not to be done in a common earthenware retort, because it contains too much of the oxides of iron and manganese, but in a perfectly

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of water and leaving the carbon. Hence its blackening power. When diluted, it acts in a totally different way. Of course if it be an acid in the last case, it cannot be so in the first. In evolving carbon by its action on alcohol, it is precisely analogous to potash, which darkens that fluid, and evolves a carbonaceous resin, which may be seen when the alcoholic solution of that alkali is evaporated, in order to obtain the hydrate.

It seems to me that the galvanic fluid is the acidifying principle, and that the acid state is the consequence of galvanic arrangements or polarities. It is known that moisture is indispensable to the efficiency of these.

On adding water to concentrated sulphuric acid, the hydrogen and oxygen severally go to the different poles of the previous compound. Hence the hydrogen evolved by iron or zinc and diluted sulphuric acid, does not come from a simultaneous, but a previous decomposition of water.

white porcelain retort. Four or five pounds of nitrate of barytes may be decomposed at once, and the process will require about three hours The barytes thus procured will contain a considerable quantity of silex and alumina; but it will have only very minute traces of manganese and iron, a circumstance of essential importance. 3. The barytes, divided by a knife into pieces as large as the end of the thumb, should then be placed in a luted tube of glass. This tube should be long and large enough to contain from 2½ to 3½ libs. It is to be surrounded with fire, and heated to dull redness, and then a current of dry oxygen gas is to be passed through it. However rapid the current, the gas is completely absorbed; so that when it passes by the small tube, which ought to terminate the larger one, it may be concluded that the deutoxide of barium is completed. It is, however, right to continue the current for seven or eight minutes more. Then the tube being nearly cold, the deutoxide, which is of a light grey colour, is taken out, and preserved in stoppered bottles. When this is moistened it falls to powder, without much increase of temperature. If in this state it be mixed with seven or eight times its weight of water, and a dilute acid be poured in, it dissolves gradually by agitation, without the evolution of any gas. The solution is neutral, or has no action on turnsole or turmeric. When we add to this solution the requisite quantity of sulphuric acid, a copious precipitate of barytes falls, and the filtered liquor is merely water, holding in solution the oxygenized acid, or deutoxide of hydrogen, combined with the acid itself.

The class of acids has been distributed into three orders, according as they are derived from the mineral, the vegetable, or the animal kingdom. But a more specific distribution is now requisite. They have also been arranged into those which have a single, and those which have a compound basis or radical. But this arrangement is not only vague, but liable in other respects to considerable objections. The chief advantage of a classification is to give general views to beginners in the study, by grouping together such substances as have analogous properties or composition. These objects, it is hoped, will be tolerably well attained by the following divisions and subdivisions.

Division 1st. Acids from inorganic nature, or which are procurable without having recourse to animal or vegetable products.

Division 2d. Acids elaborated by means of organization.

The first group is subdivided into three families, 1st, Oxygen acids; 2d, Hydrogen acids; 3d, Acids destitute of both these supposed acidifiers.

Family 1st.—Oxygen acids.

Section 1st, Non-metallic.

1. Boracic.
2. Carbonic.
3. Chloric.
4 Perchloric.
5. Chloro-carbonic.
6. Nitrous.
7. Nitric.
8. Iodic.
9. Hypophosphorous.
10. Phosphorous.
11. Phosphoric.
12. Hyposulphurous.
13. Sulphurous.
14. Sulphuric.
15. Hyposulphuric.
16. Cyanic?

Section 2d, Oxygen acids.—Metallic.

1. Arsenic.
2. Arsenious.
3. Antimonious.
4. Antimonic.
5. Chromic.
6. Columbic.
7. Molybdic.
8. Molybdous.
9. Tungstic.

Family 2d.—Hydrogen acids.

1. Fluoric.
2. Hydriodic.
3. Hydrochloric.
4. Ferroprussic.
5. Hydroprussic.
6. Hydrosulphurous.
7. Hydrotellurous.
8. Sulphuroprussic.

Family 3d.—Acids without oxygen or hydrogen.

1. Chloriodic.
2. Chloroprussic.
3. Fluoboric.
4. Fluosilicic.

Division 2d.—Acids of organic origin.

1. Aceric.
2. Acetic.
3. Amniotic.
4. Benzoic.
5. Boletic.
6. Camphoric.
7. Caseic.
8. Citric.
9. Formic.
10. Fungic.
11. Gallic.
12. Kinic.
13. Laccic.
14. Lactic.
15. Lampic.
16. Lithic.
17. Malic.
18. Meconic.
19. Menispermic.
20. Margaric.
21. Melassic.
22. Mellitic.
23. Moroxylic.
24. Mucic.
25. Oleic.
26. Oxalic.
27. Purpuric.
28 Pyrolithic.
29. Pyromalic.
30. Pyrotartaric.
31. Rosacic.
32. Saclactic.
33. Sebacic.
34. Suberic.
35. Succinic.
36. Sulphovinic?
37. Tartaric.
38. Zumic.

The acids of the last division are all decomposable at a red heat, and afford generally carbon, hydrogen, oxygen, and in some few cases also nitrogen. The mellitic is found like amber in wood coal, and like it, is undoubtedly of organic origin. We shall treat of them all in alphabetical order, only joining those acids together which graduate, so to speak, into each other, as hyposulphurous, sulphurous and sulphuric.*

* Acid (Aceric). A peculiar acid said to exist in the juice of the maple. It is decomposed by heat, like the other vegetable acids.*

* Acid (Acetic). The same acid which, in a very dilute and somewhat impure state, is called vinegar.

This acid is found combined with potash in the juices of a great many plants; particularly the sambucus nigra, phœnix dactilifera, galium verum, and rhus typhinus. Sweat, urine, and even fresh milk contain it. It is frequently generated in the stomachs of dyspeptic patients. Almost all dry vegetable substances, and some animal, subjected in close vessels to a red heat, yield it copiously. It is the result likewise of a spontaneous fermentation, to which liquid vegetable, and animal matters are liable. Strong acids, as the sulphuric and nitric, develope the acetic by their action on vegetables. It was long supposed, on the authority of Boerhaave, that the fermentation which forms vinegar is uniformly preceded by the vinous. This is a mistake. Cabbages sour in water, making sour crout; starch in starch-makers' sour waters; and dough itself, without any previous production of wine.

The varieties of acetic acids known in commerce are four: 1st, Wine vinegar; 2d, Malt vinegar; 3d, Sugar vinegar; 4th, Wood vinegar. We shall describe first the mode of making these commercial articles, and then that of extracting the absolute acetic acid of the chemist, either from these vinegars, or directly from chemical compounds, of which it is a constituent.

The following is the plan of making vinegar at present practised in Paris. The wine destined for vinegar is mixed in a large tun with a quantity of wine lees, and the whole being transferred into cloth-sacks, placed within a large iron-bound vat, the liquid matter is extruded through the sacks by superincumbent pressure. What passes through is put into large casks, set upright, having a small aperture in their top. In these it is exposed to the heat of the sun in summer, or to that of a stove in winter. Fermentation supervenes in a few days. If the heat should then rise too high it is lowered by cool air, and the addition of fresh wine. In the skilful regulation of the fermentative temperature consists the art of making good wine vinegar. In summer the process is generally completed in a fortnight; in winter double the time is requisite. The vinegar is then run off into barrels, which contain several chips of birch-wood. In about a fortnight it is found to be clarified, and is then fit for the market. It must be kept in close casks.

The manufacturers at Orleans prefer wine of a year old for making vinegar. But if by age the wine has lost its extractive matter, it does not readily undergo the acetous fermentation. In this case, acetification, as the French term the process, may be determined by adding slips of vines, bunches of grapes or green woods. It has been asserted that alcohol, added to fermentable liquor, does not increase the product of vinegar. But this is a mistake. Stahl observed long ago, that if we moisten roses, or lilies with alcohol, and place them in vessels in which they are stirred from time to time, vinegar will be formed. He also informs us, if after abstracting the citric acid from lemon juice by crabs' eyes (carbonate of lime), we add a little alcohol to the supernatent liquid, and place the mixture in a proper temperature, vinegar will be formed.

Chaptal says, that two pounds of weak spirits, sp. gr. 0.985, mixed with 300 grains of beer yeast, and a little starch water, produced extremely strong vinegar. The acid was developed on the 5th day. The same quantity of starch and yeast, without the spirit, fermented more slowly, and yielded a weaker vinegar. A slight motion is found to favour the formation of vinegar, and to endanger its decomposition after it is made. Chaptal ascribes to agitation the operation of thunder; though it is well known, that when the atmosphere is highly electrified, beer is apt to become suddenly sour, without the concussion of a thunder-storm. In cellars exposed to the vibrations occasioned by the rattling of carriages, vinegar does not keep well. The lees, which had been deposited by means of isinglass and repose, are thus jumbled into the liquor, and make the fermentation recommence.

Almost all the vinegar of the north of France being prepared at Orleans, the manufactory of that place has acquired such celebrity, as to render their process worthy of a separate consideration.

The Orleans' casks contain nearly 400 pints of wine. Those which have been already used are preferred. They are placed in three rows, one over another, and in the top have an aperture of two inches diameter, kept always open. The wine for acetification is kept in adjoining casks, containing beech shavings, to which the lees adhere. The wine thus clarified is drawn off to make vinegar. One hundred pints of good vinegar, boiling hot, are first poured into each cask, and left there for eight days. Ten pints of wine are mixed in, every eight days, till the vessels are full. The vinegar is allowed to remain in this state fifteen days, before it is exposed to sale.

The *used* casks, called *mothers*, are never emptied more than half, but are successively filled again, to acetify new portions of wine. In order to judge if the *mother* works, the vinegar makers plunge a spatula into the liquid; and according to the quantity of froth which the spatula shows, they add more or less wine. In summer, the atmospheric heat is sufficient. In winter, stoves heated to about 75° Fahr. maintain the requisite temperature in the manufactory.

In some country districts, the people keep in a place, where the temperature is mild and equable, *a vinegar cask*, into which they pour such wine as they wish to acetify; and it is always preserved full, by replacing the vinegar drawn off, by new wine. To establish this household manufacture, it is only necessary to buy at first a small cask of good vinegar. At Gand a vinegar from beer is made, in which the following proportions of grain are found to be most advantageous:—

1880 Paris lbs.	malted barley.
700	wheat.
500	buckwheat.

These grains are ground, mixed, and boiled, along with twenty-seven casks-full of river water, for three hours. Eighteen casks of good beer for vinegar are obtained. By a subsequent decoction, more fermentable liquid is extracted, which is mixed with the former. The whole brewing yields 3000 English quarts.

In this country, vinegar is usually made from malt. By mashing with hot water, 100 gallons of wort are extracted in less than two hours from 1 boll of malt. When the liquor has fallen to the temperature of 75° Fahr. 4 gallons of the barm of beer are added. After thirty-six hours it is racked off into casks, which are laid on their sides, and exposed, with their bung-holes loosely covered, to the influence of the sun in summer; but in winter they are arranged in a stove-room. In three months this vinegar is ready for the manufacture of sugar of *lead*. To make vinegar for domestic use, however, the process is somewhat different. The above liquor is racked off into casks placed upright, having a false cover pierced with holes fixed at about a foot from their bottom. On this a considerable quantity of *rape*, or the refuse from the makers of British wine, or otherwise a quantity of low priced raisins, is laid. The liquor is turned into another barrel every twenty-four hours, in which time it has begun to grow warm. Sometimes, indeed, the vinegar is fully fermented, as above, without the rape, which is added towards the end, to communicate flavour. Two large casks are in this case worked together, as is described long ago by Boerhaave, as follows.

"Take two large wooden vats, or hogsheads, and in each of these place a wooden grate or hurdle, at the distance of a foot from the bottom. Set the vessel upright, and on the grate place a moderately close layer of green twigs, or fresh cuttings of the vine. Then fill up the vessel with the footstalks of grapes, commonly called the rape, to the top of the vessel, which must be left quite open.

"Having thus prepared the two vessels, pour into them the wine to be converted into vinegar, so as to fill one of them quite up, and the other but half full. Leave them thus for twenty-four hours, and then fill up the half filled vessel with liquor from that which is quite full, and which will now in its turn only be left half full. Four-and-twenty hours afterwards repeat the same operation, and thus go on, keeping the vessels alternately full and half full during twenty-four hours, till the vinegar be made. On the second or third day there will arise in the half filled vessel, a fermentative motion, accompanied with a sensible heat, which will gradually increase from day to day. On the contrary, the fermenting motion is almost imperceptible in the full vessel; and as the two vessels are alternately full and half full, the fermentation is by this means in some measure interrupted, and is only renewed every other day in each vessel.

"When this motion appears to have entirely ceased, even in the half filled vessel, it is a sign that the fermentation is finished; and therefore the vinegar is then to be put into casks close stopped, and kept in a cool place.

"A greater or less degree of warmth accelerates or checks this, as well as the spirituous fermentation. In France it is finished in about fifteen days, during the summer; but if the heat of the air be very great, and exceed the twenty-fifth degree of Reaumur's thermometer, (88¼° Fahr.) the half filled vessel must be filled up every twelve hours; because, if the fermentation be not so checked in that time, it will become violent, and the liquor will be so heated, that many of the spirituous parts, on which the strength of the vinegar depends, will be dissipated, so that nothing will remain after the fermentation but a vapid liquor, sour indeed, but effete. The better to prevent the dissipation of the spirituous parts, it is a proper and usual precaution to close the mouth of the half filled vessel, in which the liquor ferments, with a cover made of oak wood. As to the full vessel, it is always left open, that the air may act freely on the liquor it contains; for it is not liable to the same inconveniences, because it ferments but very slowly."

Good vinegar may be made from a weak sirup, consisting of 18 oz. of sugar to every gallon of water. The yeast and rape are to be here used, as above described. Whenever the vinegar (from the taste and flavour) is considered to be complete, it ought to be decanted into tight barrels or bottles, and well secured from access of air. A momentary ebullition before it is bottled is found favourable to its preservation. In a large manufactory of malt vinegar, a considerable revenue is derived from the sale of yeast to the bakers. Vinegar obtained by the preceding methods has more or less of a brown colour, and a peculiar but rather grateful smell. By distillation in glass vessels the colouring matter, which resides in a mucilage, is separated, but the fragrant odour is generally replaced by an empyreumatic one. The best French wine vinegars, and also some from malt, contain a little alcohol, which comes over early with the watery part, and renders the first product of distillation scarcely denser, sometimes even less dense than water. It is accordingly rejected.—Towards the end of the distillation the empyreuma increases. Hence only the intermediate portions are retained as distilled vinegar. Its specific gravity varies from 1.005 to 1.015, while that of common vinegar of equal strength varies from 1.010 to 1.025.

A crude vinegar has been long prepared for the calico printers, by subjecting wood in iron retorts to a strong red heat. The following arrangement of apparatus has been found to answer well. A series of cast-iron cylinders, about 4 feet diameter, and 6 feet long, are built horizontally in brick work, so that the flame of one furnace may play round about two cylinders. Both ends project a little from the brick work. One of them has a disc of cast-iron well fitted and firmly bolted to it, from the centre of which disc an iron tube about 6 inches diameter proceeds, and enters at a right angle the *main* tube of refrigeration. The diameter of this tube may be from 9 to 14 inches, according to the number of cylinders. The other end of the cylinder is called the mouth of the retort. This is closed by a disc of iron, smeared round its edge with clay-lute, and secured in its place by wedges. The charge of wood for such a cylinder is about 8 cwt. The hard woods, oak, ash, birch, and beech, are alone used. Fir does not answer. The heat is kept up during the day-time, and the furnace is allowed to cool during the night. Next morning the door is opened, the charcoal removed, and a new charge of wood is introduced. The average product of crude vinegar called pyrolignous acid is 35 gallons. It is much contaminated with tar; is of a deep brown colour; and has a sp. gr. of 1.025. Its total weight is therefore about 300 lbs. But the residuary charcoal is found to weigh no more than one-fifth of the wood employed. Hence nearly one half of the ponderable matter of the wood is dissipated in incondensable gases. Count Rumford states, that charcoal is equal in weight to more than four-tenths of the wood from which it is made. And M. Clement says that it is equal to one-half. The Count's error seems to have arisen from the slight heat of an oven to which his wood was exposed in a glass cylinder. The result now given is the experience of an eminent manufacturing chemist at Glasgow. The crude pyrolignous acid is rectified by a second distillation in a copper still, in the body of which about 20 gallons of viscid tarry matter are left from every 100. It has now become a transparent brown vinegar, having a considerable empyreumatic smell, and a sp. gr. of 1.013. Its acid powers are superior to those of the best household vinegar, in the proportion of 3 to 2. By redistillation, saturation with quick-lime, evaporation of the liquid acetate to dryness, and gentle torrefaction, the empyreumatic matter is so completely dissipated, that on decomposing the calcareous salt by sulphuric acid, a pure, perfectly colourless, and grateful vinegar rises in distillation. Its strength will be proportional to the concentration of the decomposing acid.

The acetic acid of the chemist may be prepared in the following modes: 1st, Two parts of fused acetate of potash with one of the strongest oil of vitriol yield, by slow distillation from a glass retort into a refrigerated receiver, concentrated acetic acid. A small portion of sulphurous acid, which contaminates it, may be removed by redistillation, from a little acetate of lead. 2d, Or 4 parts of good sugar of lead, with 1 part of sulphuric acid treated in the same way, afford a slightly weaker acetic acid. 3d, Gently calcined sulphate of iron, or green vitriol, mixed with sugar of lead in the proportion of 1 of the former to 2½ of the latter, and carefully distilled from a porcelain retort into a cooled receiver, may be also considered a good economical process. Or without distillation, if 100 parts of well dried acetate of lime be cautiously added to 60 parts of strong sulphuric acid, diluted with 5 parts of water, and digested for 24 hours, and strained, a good acetic acid, sufficiently strong for every ordinary purpose, will be obtained.

The distillation of acetate of copper or of lead *per se*, has also been employed for obtaining strong acid. Here, however, the product is mixed with a portion of the fragrant pyro-acetic spirit, which it is troublesome to get rid of. Undoubtedly the best process for the strong acid is that first described, and the cheapest the second or third. When of the utmost possible strength its sp. gravity is 1. 062. At the temperature of 50° F. it assumes the solid form, crystallizing in oblong rhomboidal plates. It has an extremely pungent odour, affecting the nostrils and eyes even painfully, when its vapour is incautiously snuffed up. Its taste is eminently acid and acrid. It excoriates and inflames the skin.

The purified wood vinegar, which is used for pickles and culinary purposes, has commonly a specific gravity of about 1.009; when it is equivalent in acid strength to good wine or malt vinegar of

1.014. It contains about of $\frac{1}{20}$ its weight of absolute acetic acid, and $\frac{19}{20}$ of water. An excise duty of 4d. is levied on every gallon of vinegar of the above strength. This, however, is not estimated directly by its sp. gr. but by the sp. gr. which results from its saturation with quick-lime. The decimal number of the sp. gr. of the calcareous acetate, is nearly double that of the pure wood vinegar. Thus 1.009 in vinegar, becomes 1.018 in liquid acetate. But the vinegar of fermentation = 1.014 will become only 1.023 in acetate, from which, if 0.005 be subtracted for mucilage or extractive, the remainder will agree with the density of the acetate from wood. A glass hydrometer of Fahrenheit's construction is used for finding the specific gravities. It consists of a globe about 3 inches diameter, having a little ballast ball drawn out beneath, and a stem above of about 3 inches long, containing a slip of paper with a transverse line in the middle, and surmounted with a little cup for receiving weights or poises. The experiments on which this instrument, called an *Acetometer*, is constructed, have been detailed in the sixth volume of the Journal of Science. They do not differ essentially from those of Mollerat. The following points were determined by this chemist. The acid of sp. gr. 1.063 requires 2½ times its weight of crystallized subcarbonate of soda for saturation, whence M. Thenard regards it as a compound of 11 of water, and 89 of real acid in the 100 parts. Combined with water in the proportion of 100 to 112.2, it does not change its density, but it then remains liquid several degrees below the freezing point of water. By diluting it with a smaller quantity of water, its sp. gr. augments, a circumstance peculiar to this acid. It is 1.079, or at its *maximum*, when the water forms one-third of the weight of the acid.—*Ann. de Chimie, tom.* 66.

The following table is given by Messrs Taylor as the basis of their acetometer:—

Revenue proof acid, called by the manufacturer No. 24.

sp. gr.	1.0085 contains real acid in 100,	5
	1.0170 - - - - - - - - -	10
	1.0257 - - - - - - - - -	15
	1.0320 - - - - - - - - -	20
	1.0470 - - - - - - - - -	30
	1.0580 - - - - - - - - -	40

An acetic acid of very considerable strength may also be prepared by saturating perfectly dry charcoal with common vinegar, and then distilling. The water easily comes off, and is separated at first; but a stronger heat is required to expel the acid. Or by exposing vinegar to very cold air, or to freezing mixtures, its water separates in the state of ice, the interstices of which are occupied by a strong acetic acid, which may be procured by draining. The acetic acid or radical vinegar of the apothecaries, in which they dissolve a little camphor, or fragrant essential oil, has a specific gravity of about 1.070. It contains fully 1 part of water to 2 of the crystallized acid. The pungent smelling salt consists of sulphate of potash moistened with that acid. Acetic acid acts on tin, iron, zinc, copper, and nickel; and it combines readily with the oxides of many other metals, by mixing a solution of their sulphates with that of an acetate of lead.

This acid, as it exists in the acetates of barytes and lead, has been analyzed by M. M. Gay-Lussac and Thenard, and also by Berzelius.

Gay-Lussac found 50.224 carbon, 5.629 hydrogen, and 44.147 oxygen; or, in other terms, 50.224 carbon, 49.665 of water, or its elementary constituents, and 0.111 hydrogen in excess.

Berzelius.—46.83 carb. 6.35 hydr. and 46.82 oxygen in the hundred parts.

Their methods are described under VEGETABLE (ANALYSIS). By saturating known weights of bases with acetic acid, and ascertaining the quantity of acetates obtained after cautious evaporation to dryness, Berzelius obtained with lime (3.56) 6.5 for the prime equivalent of acetic acid, and with yellow oxide of lead 6.432. Recent researches, which will be published in a detailed form, induce me to fix the prime of acetic acid at 6.63. It would seem to consist, by Berzelius's analysis, of

3	Primes of hydrogen	3.75	6.2
4	carbon	30.	46.9
3	oxygen	30.	46.9
		63.75	100.0

The quantity of hydrogen is probably much underrated. Acetic acid dissolves resins, gum-resins, camphor, and essential oils. Its odour is employed in medicine to relieve nervous headaches, fainting fits, or sickness occasioned by crowded rooms. In a slightly dilute state, its application has been found to check hemorrhagy from the nostrils. Its anticontagious powers are now little trusted to. It is very largely used in calico printing. Moderately rectified pyrolignous acid has been recommended for the preservation of animal food; but the empyreumatic taint it communicates to bodies immersed in it, is not quite removed by their subsequent ebullition in water. See Acid, Pyrolignous).

Acetic acid and common vinegar are sometimes fraudulently mixed with sulphuric acid to give them strength. This adulteration may be detected by the addition of a little chalk, short of their saturation. With pure vinegar the calcareous base forms a limpid solution, but with sulphuric acid a white insoluble gypsum. Muriate of barytes is a still nicer test. British fermented vinegars are allowed by law to contain a little sulphuric acid, but the quantity is frequently exceeded. Copper is discovered in vinegars by supersaturating them with ammonia, when a fine blue colour is produced; and lead by sulphate of soda, hydrosulphurets, sulphuretted hydrogen, and gallic acid. None of these should produce any change on genuine vinegar. See LEAD.*

* ACID (OXY-ACETIC). Acetic acid dissolves deutoxide of barium without effervescence. By precipitating the barytes with sulphuric acid, there remains an oxygenized acid, which, being saturated with potash, and heated, allows a great quantity of oxygen gas to escape. There is disengaged at the same time a notable quantity of carbonic acid gas. This shows that the oxygen, when assisted by heat, unites in part with the carbon, and doubtless likewise with the hydrogen of the acid. It is in fact acetic deutoxide of hydrogen.

Salts consisting of the several bases, united in definite proportions to acetic acid, are called acetates. They are characterized by the pungent smell of vinegar, which they exhale on the affusion of sulphuric acid; and by their yielding on distillation in a moderate red heat a very light, odorous, and combustible liquid called pyro-acetic (SPIRIT); which see. They are all soluble in water; many of them so much so as to be uncrystallizable. About 30 different acetates have been formed, of which only a very few have been applied to the uses of life.*

The acetic acid unites with all the alkalis and most of the earths, and with these bases it forms compounds, some of which are crystallizable, and others have not yet been reduced to a regularity of figure. The salts it forms are distinguished by their great solubility; their decomposition by fire, which carbonizes them; the spontaneous alteration of their solution; and their decomposition by a great number of acids, which extricate from them the acetic acid in a concentrated state. It unites likewise with most of the metallic oxides.

With barytes the saline mass formed by the acetic acid does not crystallize; but, when evaporated to dryness, it deliquesces by exposure to air. This mass is not decomposed by acid of arsenic. By spontaneous evaporation, however, it will crystallize in fine transparent prismatic needles, of a bitterish acid taste, which do not deliquesce when exposed to the air, but rather effloresce.

With potash this acid unites, and forms a deliquescent salt scarcely crystallizable, called formerly foliated earth of tartar, and regenerated tartar. The solution of this salt, even in closely stopped vessels, is spontaneously decomposed: it deposites a thick, mucous, flocculent sediment, at first gray, and at length black; till at the end of a few months nothing remains in the liquor but carbonate of potash, rendered impure by a little coaly oil.

With soda it forms a crystallizable salt, which does not deliquesce. This salt has very improperly been called mineral foliated earth. According to the new nomenclature it is acetate of soda.

The salt formed by dissolving chalk or other calcareous earth in distilled vinegar, formerly called salt of chalk, or fixed vegetable sal ammoniac, and by Bergman calx acetata, has a sharp bitter taste, appears in the form of crystals resembling somewhat ears of corn, which remain dry when exposed to the air, unless the acid has been super-abundant, in which case they deliquesce. By distilling without addition, the acid is separated from the earth, and appears in the form of a white, acid, and inflammable vapour, which smells like acetic ether, somewhat empyreumatic, and which condenses into a reddish brown liquor.

This liquor, being rectified, is very volatile and inflammable: upon adding water it acquires a milky appearance, and drops of oil seem to swim upon the surface. After the rectification, a reddish brown liquor remains behind in the retort, together with a black thick oil. When this earthy salt is mixed with a solution of sulphate of soda, the calcareous earth is precipitated along with the sulphuric acid; the acetic acid uniting with the soda, makes a crystallizable salt, by the calcination of which to whiteness, the soda may be obtained. This acetic calcareous salt is not soluble in spirit of wine.

Of the acetate of strontian little is known, but that it has a sweet taste, is very soluble, and is easily decomposed by a strong heat.

The salt formed by uniting vinegar with ammonia, called by the various names of spirit of Mindererus, liquid sal ammoniac, acetous sal ammoniac, and by Bergman alkali volatile acetatum, is generally in a liquid state, and is commonly believed not to be crystallizable, as in distillation it passes entirely over into the receiver. It nevertheless may be reduced into the form of small needle-shaped crystals, when this liquor is evaporated to the consistence of a sirup.

Westendorf, by adding his concentrated vinegar to carbonate of ammonia, obtained a pellucid liquid, which did not crystallize; and which by distillation was totally expelled from the retort, leaving only a white spot. In the receiver, under the clear fluid, a transparent saline mass appeared, which being separated from the fluid, and exposed to gentle warmth, melted and threw out abundance of white vapours, and in a few minutes shot into sharp crystals resembling those of nitre. These crystals remain unchanged while cold, but they melt at 120° and evaporate at about 250°. Their taste at first is sharp and then sweet, and they possess the general properties of neutral salts.

With magnesia the acetic acid unites, and, after a perfect saturation, forms a viscid saline mass, like a solution of gum arabic, which does not shoot into crystals, but remains deliquescent, has a taste sweetish at first, and afterwards bitter, and is soluble in spirit of wine. The acid of this saline mass may be separated by distillation without addition.

Glucine is readily dissolved by acetic acid. This solution, as Vauquelin informs us, does not crystallize; but is reduced by evaporation to a gummy substance, which slowly becomes dry and brittle; retaining a kind of ductility for a long time. It has a saccharine and pretty strongly astringent taste, in which that of vinegar however, is distinguishable.

Yttria dissolves readily in acetic acid, and the solution yields by evaporation crystals of acetate of yttria. These have commonly the form of thick six-sided plates, and are not altered by exposure to the air.

Alumine, obtained by boiling alum with alkali, and edulcorated by digesting in an alkaline lixivium, is dissolved by distilled vinegar in a very inconsiderable quantity. A considerable quantity of the earth of alum, precipitated by alkali, and edulcorated by hot water in Margraff's manner, is soluble in vinegar, and a whitish saline mass is then obtained, which is not crystallizable. From this mass a concentrated acetic acid may be obtained by distillation. Or to a boiling solution of alum in water gradually add a solution of acetate of lead till no further precipitate ensues. The sulphate of lead having subsided, decant the supernatant liquor, evaporate, and the acetate of alumine may be obtained in small needle-shaped crystals, having a strong styptic and acetous taste. This salt is of great use in dyeing and calico printing. See Alumina.

Acetate of zircone may be formed by pouring acetic acid on newly precipitated zircone. It has an astringent taste. It does not crystallize; but, when evaporated to dryness, forms a powder, which does not attract moisture from the air. It is very soluble both in water and alcohol; and is not so easily decomposed by heat as nitrate of zircone.

The acetic acid has no action upon siliceous earth; for the needle-shaped crystals observed by Durande in a mixture of vinegar with the earth precipitated from a liquor of flints, do not prove the solubility of siliceous earth, as Leonhardi observes.

Concerning the action of vinegar on alcohol, see Ether. This acid has no effect upon fat oils, except that when distilled together, some kind of mixture takes place, as the Abbé Rozier observes. Neither does distilled vinegar act upon essential oils; but Westendorf's concentrated acid dissolved about a sixth part of oil of rosemary, or one half its weight of camphor; which latter solution was inflammable; and the camphor was precipitated from it by adding water.

Vinegar dissolves the true gums, and partly the gum-resins, by means of digestion.

Boerhaave observes, that vinegar by long boiling dissolves the flesh, cartilages, bones, and ligaments of animals.

Acid. (Amniotic). On evaporating the liquor amnii of the cow to one-fourth, Vauquelin and Buniva found, that crystals form in it by cooling. These are contaminated by a portion of extractive matter, from which they may be freed by washing with a very small quantity of water. These crystals are white and shining, slightly acid to the taste, redden litmus paper, and are a little more soluble in hot than cold water. They are likewise soluble in alcohol. On ignited coals they swell, turn black, give out ammonia and prussic acid, and leave a bulky coal. With the alkalis this acid forms very soluble salts, but it does not decompose the carbonate without the assistance of heat. It does not precipitate the earthy salts, or the nitrates of mercury, lead, or silver. The acids precipitate it from its combinations with alkalis in a white crystaline powder. Whether it exist in the amniotic liquor of any other animal is not known.

Acid (Arsenic). The earlier chemists were embarrassed in the determination of the nature of the white sublimate, which is obtained during the roasting of cobalt and other metallic ores, known in commerce by the name of arsenic: its solubility in water, its power of combining with metals in their simple state, together with other apparently heterogeneous properties, rendered it difficult to determine whether it ought to be classed with metals or salts. Subsequent discoveries have shown the relation it bears to both. When treated with combustible matter, in close vessels, it sublimes in the metallic form, (See Arsenic); combustion, or any analogous process, converts it into an oxide; and when the combustion is carried still further, the arsenical basis becomes itself converted into an acid.

We are indebted to the illustrious Scheele for the discovery of this acid, though Macquer had before noticed its combinations. It may be obtained by various methods. If six parts of nitric acid be poured on one of the concrete arsenious acid, or white arsenic of the shops, in the pneumato-chemical apparatus, and heat be applied, nitrous gas will be evolved, and a white concrete substance, differing in its properties from the arsenious acid, will remain in the retort. This is the arsenic acid. It may equally be procured by means of aqueous chlorine, or by heating concentrated nitric acid with twice its weight of the solution of the arsenious acid in muriatic acid. The concrete acid should be exposed to a dull red heat for a few minutes. In either case an acid is obtained, that does not crystallize, but attracts the moisture of the air, has a sharp caustic taste, reddens blue vegetable colours, is fixed in the fire, and of the specific gravity of 3.391.

If the arsenic acid be exposed to a red heat in a glass retort, it melts and becomes transparent, but assumes a milky hue on cooling. If the heat be increased, so that the retort begins to melt, the acid boils, and sublimes into the neck of the retort. If a covered crucible be used instead of the glass retort, and a violent heat applied, the acid boils strongly, and in a quarter of an hour begins to emit fumes. These, on being received in a glass bell, are found to be arsenious acid; and a small quantity of a transparent glass, difficult to fuse, will be found lining the sides of the crucible. This is arseniate of alumina.

Combustible substances decompose this acid. If two parts of arsenic acid be mixed with about one of charcoal, the mixture introduced into a glass retort, coated, and a matrass adapted to it; and the retort then gradually heated in a reverberatory furnace, till the bottom is red; the mass will be inflamed violently, and the acid reduced, and rise to the neck of the retort in the metallic state mixed with a little oxide and charcoal powder. A few drops of water, devoid of acidity, will be found in the receiver.

With sulphur the phenomena are different. If a mixture of six parts of arsenic acid, and one of powdered sulphur, be digested together, no change will take place; but on evaporating to dryness, and distilling in a glass retort, fitted with a receiver, a violent combination will ensue, as soon as the mixture is sufficiently heated to melt the sulphur. The whole mass rises almost at once, forming a red sublimate, and sulphurous acid passes over into the receiver.

If pure arsenic acid be diluted with a small quantity of water, and hydrogen gas, as it is evolved by the action of sulphuric acid on iron, be received into this transparent solution, the liquor grows turbid, and a blackish precipitate is formed, which, being well washed with distilled water, exhibits all the phenomena of arsenic. Sometimes, too, a blackish gray oxide of arsenic is found in this process.

If sulphuretted hydrogen gas be employed instead of simple hydrogen gas, water and a sulphuret of arsenic are obtained.

With phosphorus, phosphoric acid is obtained, and a phosphuret of arsenic, which sublimes.

The arsenic acid is much more soluble than the arsenious. According to Lagrange, two parts of water are sufficient for this purpose. It cannot be crystallized by any means; but, on evaporation, assumes a thick honey-like consistence.

No acid has any action upon it: if some of them dissolve it by means of the water that renders them fluid, they do not produce any alteration in it. The boracic and phosphoric are vitrifiable with it by means of heat, but without any material alteration in their natures. If phosphorous acid be heated upon it for some time, it saturates itself with oxygen, and becomes phosphoric acid.

The arsenic acid combines with the earthy and alkaline bases, and forms salts very different from those furnished by the arsenious acid.

All these arseniates are decomposable by charcoal, which separates arsenic from them by means of heat.

* Berzelius, from the result of accurate experiments on the arseniates of lead and barytes, infers the prime equivalent of arsenic acid to be 7.25, oxygen being 1.0; but Dr. Thomson, from his experiments on the arseniates of potash and soda, conceives that the double of the above number ought to be preferred, viz. 14.5. *Ann. of Phil. vol.* xv.

On the latter supposition, Berzelius's insoluble salts will consist of two primes of base and one of acid; and the acid itself will be a compound of 5 of oxygen = 5, + 9.5. of the metallic base = 14.5; for direct experiments have shown it to consist of 100 metal, and from 52 to 53 oxygen. But 152.5 : 100 : : 14.5 : 9.5 nearly.

All its salts, with the exception of those of potash, soda, and ammonia, are insoluble in water; but except arseniate of bismuth, and one or two more, very soluble in an excess of arsenic acid. Hence, after barytes or oxide of lead has been precipitated by this acid, its farther addition redissolves the precipitate. This is a useful criterion of the acid, joined to its reduction to the metallic state by charcoal, and the other characters already detailed. Sulphuric acid decomposes the arseniates at a low temperature, but the sulphates are decomposed by arsenic acid at a red heat, owing to the greater fixity of the latter. Phosphoric, nitric, muriatic, and fluoric acids, dissolve, and probably convert into subsalts all the arseniates. The whole of them, as well as arsenic acid itself when decomposed at a red heat by charcoal, yield the characteristic garlic smell of the metallic vapour. Nitrate of silver gives a pulverulent brick-coloured precipitate, or, according to Dr. Thomson, a flesh red, with arsenic acid. The acid itself does not disturb the transparency of a solution of sulphate of copper; but a neutral arseniate gives with it a bluish green precipitate; with sulphate of cobalt, a dirty red, and with sulphate of nickel, an apple green precipitate. These precipitates redissolve, on adding a small quantity of the acid which previously held them in solution. Orfila says, that arsenic acid gives, with acetate of copper, a bluish white precipitate, but that it exercises no action either on the muriate or acetate of cobalt; but with the ammonia-muriate it gives a rose-coloured precipitate. Arsenic acid ought to be accounted a more violent poison than even the arsenious. According to Mr. Brodie, it is absorbed, and occasions death by acting on the brain and the heart.*

The arseniate of barytes is insoluble, uncrystallizable, soluble in an excess of its acid, and decomposable by sulphuric acid, which precipitates a sulphate of barytes.

Of the arseniate of strontian nothing is known, but no doubt it resembles that of barytes.

With lime-water this acid forms a precipitate of arseniate of lime, soluble in an excess of its base, or in an excess of its acid, though insoluble alone. The acidulous arseniate of lime affords on evaporation little crystals, decomposable by sulphuric acid. The same salt may be formed by adding carbonate of lime to the solution of arsenic acid. This acid does not decompose the nitrate or muriate of lime; but the saturated alkaline arseniates decompose them by double affinity, precipitating the insoluble calcareous arseniate.

If arsenic acid be saturated with magnesia, a thick substance is formed near the point of saturation. This arseniate of magnesia is soluble in an excess of acid; and on being evaporated takes the form of a jelly, without crystallizing. Neither the sulphate, nitrate, nor muriate of magnesia is decomposed by arsenic acid, though they are by the saturated alkaline arseniates.

Arsenic acid saturated with potash does not easily crystallize. This arseniate, being evaporated to dryness, attracts the humidity of the air, and turns the sirup of violets green, without altering the solution of litmus. It fuses into a white glass, and with a strong fire is converted into an acidule, part of the alkali being abstracted by the silex and alumina of the crucible. If exposed to a red heat with charcoal in close vessels it swells up very much, and arsenic is sublimed. It is decomposed by sulphuric acid; but in the humid way the decomposition is not obvious, as the arsenic acid remains in solution. On evaporation, however, this acid and sulphate of potash are obtained.

If arsenic acid be added to the preceding salt, till it ceases to have any effect on the sirup of violets, it will redden the solution of litmus; and in this state it affords very regular and very transparent crystals, of the figure of quadrangular prisms, terminated by two tetraëdral pyramids, the angles of which answer to those of the prisms. These crystals are the arsenical neutral salt of Macquer. As this salt differs from the preceding arseniate by its crystallizability, its reddening solution of litmus, its not decomposing the calcareous and magnesian salts like it, and its capability of absorbing an additional portion of potash, so as to become neutral, it ought to be distinguished from it by the term of acidulous arseniate of potash.

With soda in sufficient quantity to saturate it, arsenic acid forms a salt crystallizable like the acidulous arseniate of potash. Pelletier says, that the crystals are hexaëdral prisms terminated by planes perpendicular to their axis. This neutral arseniate of soda, however, while it differs completely from that of potash in this respect, and in becoming deliquescent instead of crystallizable on the addition of a surplus portion of arsenic acid, resembles the arseniate of potash in its decomposition by charcoal, by acids, and by the earths.

Combined with ammonia, arsenic acid forms a salt affording rhomboidal crystals analogous to those of the nitrate of soda. The arseniate of ammonia, which is produced likewise in the decomposition of nitrate of ammonia by arsenious acid, is decomposable in two ways by the action of heat. If it be gently heated, the ammonia is evolved, and the arsenic acid is left pure. If it be exposed to a violent and rapid heat, part of the ammonia and part of the acid reciprocally decompose each other; water is formed; azotic gas is given out; and the arsenic sublimes in a shining metallic form. Magnesia partly decomposes the arseniate of ammonia, and forms a triple salt with a portion of it.

Arsenic acid saturated with alumina forms a thick solution, which, being evaporated to dryness, yields a salt insoluble in water, and decomposable by the sulphuric, nitric and muriatic acids, as well as by all the other earthy and alkaline bases. The arsenic acid readily dissolves the alumina of the crucibles in which it is reduced to a state of fusion; and thus it attacks silex also, on which it has no effect in the humid way.

We know nothing of the combination of this acid with zircone.

By the assistance of a strong fire, as Fourcroy asserts, arsenic acid decomposes the alkaline and earthy sulphates, even that of barytes; the sulphuric acid flying off in vapour, and the arseniate remaining in the retort. It acts in the same manner on the nitrate, from which it expels the pure acid. It likewise decomposes the muriates at a high temperature, the muriatic acid being evolved in the form of gas, and the arsenic acid combining with their bases, which it saturates; while the arsenious acid is too volatile to have this effect. It acts in the same manner on the fluates, and still more easily on the carbonates, with which, by the assistance of heat, it excites a brisk effervescence. Lagrange, however, denies that it acts on any of the neutral salts, except the sulphate of potash, and soda, the nitrate of potash, and the muriates of soda and ammonia, and this by means of heat. It does not act on the phosphates, but precipitates the boracic acid from solutions of borates when heated.

Arsenic acid does not act on gold or platina; neither does it on mercury or silver without the aid of a strong heat; but it oxidizes copper, iron, lead, tin, zinc, bismuth, antimony, cobalt, nickel, manganese, and arsenic.

This acid is not used in the arts, at least directly, though indirectly it forms a part of some composition used in dyeing. It is likewise one of the mineralizing acids combined by nature with some of the metallic oxides.

Acid (Arsenious). Fourcroy was the first who distinguished by this name the white arsenic of the shops, which Scheele had proved to be a compound of the metal arsenic with oxygen, and which the authors of the new chemical nomenclature had consequently termed oxide of arsenic. As, however, it manifestly exhibits the properties of an acid, though in a slight degree, it has a fair claim to the title; for many oxides and acids are similar in this, that both consist of a base united with oxygen, and the only difference between them is, that the compound in which the acid properties are manifest is termed an acid, and that in which they are not is called an oxide.

This acid, which is one of the most virulent poisons known, frequently occurs in a native state, if not very abundantly; and it is obtained in roasting several ores, particularly those of cobalt. In the chimneys of the furnaces where this operation is conducted, it generally condenses in thick semi-transparent masses; though sometimes it assumes the form of a powder, or of little needles, in which state it was formerly called flowers of arsenic.

The arsenious acid reddens the most sensible blue vegetable colours, though it turns the sirup of violets green. On exposure to the air it becomes opaque, and covered with a slight efflorescence.—Thrown on incandescent coals, it evaporates in white fumes, with a strong smell of garlic. In close vessels it is volatilized; and, if the heat be strong, vitrified. The result of this vitrification is a transparent glass, capable of crystallizing in tetraëdra, the angles of which are truncated. It is easily altered by hydrogen and carbon, which deprive it of its oxygen at a red heat, and reduce the metal, the one forming water, the other carbonic acid, with the oxygen taken from it: as it is by phosphorus, and by sulphur, which are in part converted into acids by its oxygen, and in part form an arsenical phosphuret or sulphuret with the arsenic reduced to the metallic state. Hence Margraaf and Pelletier, who particularly examined the phosphurets of metals, have asserted they might be formed with arsenious acid. Its specific gravity is 3.7.

It is soluble in thirteen times its weight of boiling water, but requires eighty times its weight of cold. The solution crystallizes, and the acid assumes the form of regular tetraëdrons according to Fourcroy; but, according to Lagrange, of octaëdrons, and these frequently varying in figure by different laws of decrement. It crystallizes much better by slow evaporation than by simple cooling.

* The solution is very acrid, reddens blue colours, unites with the earthy bases, and decomposes the alkaline sulphurets. Arsenious acid is also soluble in oils, spirits, and alcohol; the last taking up from 1 to 2 per cent. It is composed of 9.5 of metal + 3 oxygen; and its prime equivalent is therefore 12.5. Dr. Wollaston first observed, that when a mixture of it with quick-lime is heated in a glass tube, at a certain temperature, ignition suddenly pervades the mass, and metallic arsenic sublimes. As arseniate of lime is found at the bottom of the tube, we perceive that a portion of the arsenious acid is robbed of its oxygen, to complete the acidification of the rest.*

There are even some metals, which act upon the solution, and have a tendency to decompose the acid, so as to form a blackish precipitate, in which the arsenic is very slightly oxidized.

The action of the other acids upon the arsenious is very different from that which they exert on the metal arsenic. By boiling, sulphuric acid dissolves a small portion of it, which is precipitated as the solution cools. The nitric acid does not dissolve it, but by the help of heat converts it into arsenic acid. Neither the phosphoric nor the carbonic acid acts upon it; yet it enters into a vitreous combination with the phosphoric and boracic acids. The muriatic acid dissolves it by means of heat, and forms with it a volatile compound, which water precipitates; and aqueous chlorine acidifies it completely, so as to convert it into arsenic acid.

The arsenious acid combines with the earthy and alkaline bases. The earthy arseniates possess little solubility, and hence the solutions of barytes, strontian, and lime, form precipitates with that of arsenious acid.

The acid enters into another kind of combination with the earths, that formed by vitrification. Though a part of this volatile acid sublimes before the glass enters into fusion, part remains fixed in the vitrified substance, to which it imparts transparency, a homogeneous density, and considerable gravity. The arsenical glasses appear to contain a kind of triple salt, since the salt and alkalis enter into an intimate combination at the instant of fusion, and remain afterwards perfectly mixed. All of them have the inconvenience of quickly growing dull by exposure to the air.

With the fixed alkalis the arsenious acid forms thick arsenites, which do not crystallize; which are decomposable by fire, the arsenious acid being volatilized by the heat; and from which all the other acids precipitate this in powder. These saline compounds were formerly termed livers, because they were supposed to be analogous to the combinations of sulphur with the alkalis.

With ammonia it forms a salt capable of crystallization. If this be heated a little, the ammonia is decomposed, the nitrogen is evolved, while the hydrogen, uniting with part of the oxygen of the acid, forms water.

Neither the earthy nor alkaline arsenites have yet been much examined; what is known of them being only sufficient to distinguish them from the arseniates.

The nitrates act on the arsenious acid in a very remarkable manner. On treating the nitrates and arsenious acid together, the nitrous acid, or nitrous vapour, is extricated in a state very difficult to be confined, as Kunckel long ago observed; part of its oxygen is absorbed by the arsenious acid; it is thus converted into arsenic acid, and an arseniate is left in the retort. The same phenomena take place on detonating nitrates with arsenious acid; for it is still sufficiently combustible to produce a detonation, in which no sparks are seen, it is true, but with commotion and effervescence; and a true arseniate remains at the bottom of the crucible. It was in this way chemists formerly prepared their fixed arsenic, which was the acidulous arseniate of potash. The nitrate of ammonia exhibits different phenomena in its decomposition by arsenious acid, and requires considerable precaution. Pelletier, having mixed equal quantities, introduced the mixture into a large retort of coated glass, placed in a reverberatory furnace, with a globular receiver. He began with a very slight fire; for the decomposition is so rapid, and the nitrous vapours issue with such force, that a portion of the arsenious acid is carried off undecomposed, unless you proceed very gently. If due care be taken that the decomposition proceeds more slowly, nitrous acid first comes over; if the fire be continued, or increased, ammonia is next evolved; and lastly, if the fire be urged, a portion of oxide of arsenic sublimes in the form of a white powder, and a vitreous mass remains in the retort, which powerfully attacks and corrodes it. This is arsenic acid. The chlorate of potash, too, by completely oxidizing the arsenious acid, converts it into arsenic acid, which by the assistance of heat, is capable of decomposing the muriate of potash that remains.

The arsenious acid is used in numerous instances in the arts, under the name of white arsenic, or of arsenic simply. In many cases it is reduced, and acts in its metallic state.

Many attempts have been made to introduce it into medicine; but as it is known to be one of the most violent poisons, it is probable that the fear of its bad effects may deprive society of the advantages it might afford in this way. An arsenite of potash was extensively used by the late Dr. Fowler of York, who published a treatise on it, in intermittent and remittent fevers. He likewise assured the writer, that he had found it extremely efficacious in periodical headache, and as a tonic in nervous and other disorders; and that he never saw the least ill effect from its use, due precaution being employed in preparing and administering it. Externally it has been employed as a caustic to extirpate cancer, combined with sulphur, with bole, with antimony, and with the leaves of crowfoot; but it always gives great pain, and is not unattended with danger. Febure's remedy was water one pint, extract of hemlock ʒj, Goulard's extract ʒiij, tincture of opium ʒj, arsenious acid gr. x. With this the cancer was wetted morning and evening; and at the same time a small quantity of a weak solution was administered internally. A still milder application of this kind has been made from a solution of one grain in a quart of water, formed into a poultice with crumb of bread.

* It has been more lately used as an al-

terative with advantage in chronic rheumatism. The symptoms which show the system to be *arsenified* are thickness, redness, and stiffness of the *palpebræ*, soreness of the gums, ptyalism, itching over the surface of the body, restlessness, cough, pain at stomach, and headache. When the latter symptoms supervene, the administration of the medicine ought to be immediately suspended. It has also been recommended against chincough; and has been used in considerable doses with success, to counteract the poison of venemous serpents.

Since it acts on the animal economy as a deadly poison in quantities so minute as to be insensible to the taste when diffused in water or other vehicles, it has been often given with criminal intentions and fatal effects. It becomes therefore a matter of the utmost importance to present a systematic view of the phenomena characteristic of the poison, its operation, and consequences. 1st, It is a dense substance, subsiding speedily after agitation in water. I find its sp. gr. to vary from 3.728 to 3.730, which is a little higher than the number given above; 72 parts dissolve in 1000 of boiling water, of which 30 remain in it, after it cools. Cold water dissolves, however, only $\frac{3}{1000}$ or $\frac{1}{10}$ of the preceding quantity. This water makes the sirup of violets green, and reddens litmus paper. Lime water gives a fine white precipitate with it of arsenite of lime, soluble in an excess of the arsenious solution. Sulphuretted hydrogen gas, and hydrosulphuretted water precipitate a golden yellow sulphuret of arsenic. By this means $\frac{1}{100000}$ of arsenious acid may be detected in water. This sulphuret dried on a filter, and heated in a glass tube with a bit of caustic potash, is decomposed in a few minutes, and converted into sulphuret of potash, which remains at the bottom, and metallic arsenic of a bright steel lustre, which sublimes, coating the sides of the tube. The hydrosulphurets of alkalis do not affect the arsenious solution, unless a drop or two of nitric or muriatic acid be poured in, when the characteristic golden yellow precipitate falls. Nitrate of silver is decomposed by the arsenious acid, and a very peculiar yellow arsenite of silver precipitates, which however, is apt to be redissolved by nitric acid, and therefore a very minute addition of ammonia is requisite. Even this however, also, if in much excess, redissolves the silver precipitate.

As the nitrate of silver is justly regarded as one of the best precipitant tests of arsenic, the mode of using it has been a subject of much discussion. The presence of muriate of soda indeed, in the arsenical solution, obstructs, to a certain degree, the operation of this reagent. But, that salt is almost always present in the *primæ viæ*, and is a usual ingredient in soups, and other vehicles of the poison. If, after the water of ammonia has been added, by plunging the end of a glass rod dipped in it into the supposed poisonous liquid, we dip another rod into a solution of pure nitrate of silver, and transfer it into the arsenious solution, either a fine yellow cloud will be formed, or at first merely a white curdy precipitate. But at the second or third immersion of the nitrate rod, a central spot of yellow will be perceived surrounded with the white muriate of silver. At the next immersion this yellow cloud on the surface will become very conspicuous. Sulphate of soda does not interfere in the least with the silver test. The ammoniaco-sulphate, or rather ammoniaco-acetate of copper, added in a somewhat dilute state to an arsenious solution, gives a fine grass green and very characteristic precipitate. This green arsenite of copper, well washed, being acted on by an excess of sulphuretted hydrogen water, changes its colour and becomes of a brownish red. Ferro-Prussiate of potash changes it into a blood-red. Nitrate of silver converts it into the yellow arsenite of silver. Lastly, if the precipitate be dried on a filter, and placed on a bit of burning coal, it will diffuse a garlic odour. The cupreous test will detect $\frac{1}{110000}$ of the weight of the arsenic in water. The voltaic battery, made to act by two wires on a little arsenious solution placed on a bit of window-glass, developes metallic arsenic at the negative pole; and if this wire be copper, it will be whitened like tombac. We may here remark, however, that the most elegant mode of using all these precipitation reagents is upon a plane of glass, a mode practised by Dr. Wollaston in general chemical research, to an extent, and with a success, which would be incredible in other hands than his. Concentrate by heat in a capsule the suspected poisonous solution, having previously filtered it if necessary. Indeed, if it be very much disguised with animal or vegetable matters, it is better first of all to evaporate to dryness, and by a few drops of nitric acid to dissipate the organic products. The clear liquid being now placed in the middle of the bit of glass, lines are to be drawn out from it in different directions. To one of these a particle of weak ammoniacal water being applied, the weak nitrate of silver may then be brushed over it with a hair pencil. By placing the glass in different lights, either over white paper or obliquely before the eye, the slightest change of tint will be perceived. The ammoniaco-acetate should be applied to another filament of the drop, deut-acetate of iron to a third, weak ammoniaco-acetate of cobalt to a fourth, sulphuretted water to a fifth, lime water to a sixth, a drop of violet sirup to a seventh, and the two galvanic wires at the opposite edges of the whole. Thus with one single drop of solution many exact experiments may be made. But the chief, the decisive trial or *experimentum crucis* remains, which is to take a little of the dry matter, mix it with a small pinch of dry black flux, put it into a narrow glass tube sealed at one end, and after cleansing its sides with a feather, urge its bottom with a blow-pipe till it be distinctly red hot for a minute. Then garlic fumes will be smelt, and the steel-lustred coating of metallic arsenic will be seen in the tube about one-fourth of an inch above its bottom. Cut the tube across at that point by means of a fine file, detach the scale of arsenic with the point of a penknife; put a fragment of it into the bottom of a small wine glass along with a few drops of ammoniaco-acetate of copper, and triturate them well together for a few minutes with a round headed glass rod. The mazarine blue colour will soon be transmuted into a lively grass green, while the metallic scale will vanish. Thus we distinguish perfectly between a particle of metallic arsenic and one of animalized charcoal. Another particle of the scale may be placed between two smooth and bright surfaces of copper, with a touch of fine oil; and whilst they are firmly pressed together, exposed to a red heat. The tombac alloy will appear as a white stain. A third particle may be placed on a bit of heated metal, and held a little under the nostrils, when the garlic odour will be recognized. No danger can be apprehended, as the fragment need not exceed the tenth of a grain. It is to be observed, that one or two of the precipitation tests may be equivocal from admixtures of various substances. Thus tincture of ginger gives with the cupreous reagent a green precipitate;—and the writer of this article was at first led to suspect from that appearance, that an empirical tincture, put into his hands for examination, did contain arsenic. But a careful analysis satisfied him of its genuineness. Tea covers arsenic from the cupreous test. Such poisoned tea becomes by its addition of an obscure olive or violet red, but yields scarcely any precipitate. Sulphuretted hydrogen, however, throws down a fine yellow sulphuret of arsenic.

Another way of obviating all these sources of fallacy, is to evaporate carefully to dryness, and expose the residue to heat in a glass tube. The arsenic sublimes, and may be operated on without ambiguity. Mr. Orfila has gone into ample details on the modifications produced by wine, coffee, tea, broth, &c. on arsenical tests, of which a good tabular abstract is given in Mr. Thomson's London Dispensatory. But it is evident that the differences in these menstrua, as also in beers, are so great as to render precipitations and changes of colour by reagents very unsatisfactory witnesses, in a case of life and death. Hence the method of evaporation above described, should never be neglected. Should the arsenic be combined with oil, the mixture ought to be boiled with water, and the oil then separated by the capillary action of wick-threads. If with resinous substances, these may be removed by oil of turpentine, not by alcohol, (as directed by Dr. Black,) which is a good solvent of arsenious acid. It may moreover be observed, that both tea and coffee should be freed from their tannin by gelatin, which does not act on the arsenic, previous to the use of reagents for the poison. When one part of arsenious acid in watery solution is added to 10 parts of milk, the sulphuretted hydrogen present in the latter, occasions the white colour to pass into a canary yellow; the cupreous test gives it a slight green tint, and the nitrate of silver produces no visible change, though even more arsenic be added; but the hydrosulphurets throw down a golden yellow, with the aid of a few drops of an acid. The liquid contained in the stomach of a rabbit poisoned with a solution of 3 grains of arsenious acid, afforded a white precipitate with nitrate of silver, grayish white with lime water, green with the ammoniaco-sulphate, and deep yellow with sulphuretted hydrogen water.

The preceding copious description of the habitudes of arsenious acid in different circumstances, is equally applicable to the soluble arsenites. Their poisonous operation, as well as that of the arsenic acid, has been satisfactorily referred by Mr. Brodie to the suspension of the functions of the heart and brain, occasioned by the absorption of these substances into the circulation, and their consequent determination to the nervous system and the alimentary canal. This proposition was established by numerous experiments on rabbits and dogs. Wounds were inflicted, and arsenic being applied to them, it was found that in a short time death supervened with the same symptoms of inflammation of the stomach and bowels, as if the poison had been swallowed. He divides the morbid affections into three classes: 1st, Those depending on the nervous system, as palsy at first of the posterior extremities, and then of the rest of the body, convulsions, dilatation of the pupils, and general insensibility: 2d, Those which indicate disturbance in the organs of circulation; for example, the feeble, slow, and intermitting pulse, weak contractions of the heart immediately after death, and the impossibility of prolonging them, as may be done in sudden deaths from other causes, by artificial respiration: 3d, Lastly, Those which depend on lesion of the alimentary canal, as the pains of the abdomen, nauseas and vomitings, in those animals which were suffered to vomit. At one time it is the nervous system that is most remarkably affected, and at another the organs of circulation. Hence inflammation of the stomach and intestines, ought not to be considered as the immediate cause of death, in the greater number of cases of poisoning by arsenic. However, should an animal not sink under the first violence of the poison, if the inflammation has had time to be developed, there is no doubt that it may destroy life. Mr. Earle states, that a woman who had taken arsenic resisted the alarming symptoms which at first appeared, but died on the fourth day. On opening her body the mucous membrane of the stomach and intestines was ulcerated to a great extent. Authentic cases of poison are recorded, where no trace of inflammation was perceptible on the *primæ viæ*.

The symptoms of a dangerous dose of arsenic have been graphically represented by Dr. Black: "The symptoms produced by a dangerous dose of arsenic begin to appear in a quarter of an hour, or not much longer, after it is taken. First sickness, and great distress at stomach, soon followed by thirst, and burning heat in the bowels. Then come on violent vomiting, and severe cholic pains, and excessive and painful purging. This brings on faintings, with cold sweats, and other signs of great debility. To this succeed painful cramps and contractions of the legs and thighs, and extreme weakness, and death." Similar results have followed the incautious sprinking of schirrous ulcers with powdered arsenic, or the application of arsenical pastes. The following more minute specification of symptoms is given by Orfila: "An austere taste in the mouth; frequent ptyalism; continual spitting; constriction of the *pharynx* and *æsophagus*; teeth set on edge; hiccups; nausea; vomiting of brown or bloody matter; anxiety; frequent fainting fits; burning heat at the *precordia*; inflammation of the lips, tongue, palate, throat, stomach; acute pain of stomach, rendering the mildest drinks intolerable; black stools of an indescribable fœtor; pulse frequent, oppressed and irregular, sometimes slow and unequal; palpitation of the heart; *syncope*; unextinguishable thirst; burning sensation over the whole body, resembling a consuming fire; at times an icy coldness, difficult respiration, cold sweats, scanty urine, of a red or bloody appearance, altered expression of countenance, a livid circle round the eyelids, swelling and itching of the whole body, which becomes covered with livid spots, or with a miliary eruption; prostration of strength, loss of feeling, especially in the feet and hands; delirium, convulsions, sometimes accompanied with an insupportable priapism, loss of the hair, separation of the epidermis, horrible convulsions, and death."

It is uncommon to observe all these frightful symptoms combined in one individual; sometimes they are altogether wanting, as is shown by the following case, related by M. Chaussier: A robust man of middle age, swallowed arsenious acid in large fragments, and died without experiencing other symptoms than slight *syncopes*. On opening his stomach, it was found to contain the arsenious acid in the very same state in which he had swallowed it. There was no appearance whatever of erosion or inflammation in the intestinal canal. Etmuller mentions a young girl's being poisoned by arsenic, and whose stomach and bowels were sound to all appearance, though the arsenic was found in them. In general, however, inflammation does extend along the whole canal from the mouth to the *rectum*. The stomach and *duodenum* present frequently gangrenous points, escars, perforations of all their coats; the villous coat in particular, by this and all other corrosive poisons, is commonly detached, as if it were scraped off or reduced into a paste of a reddish brown colour. From these considerations we may conclude, that from the existence or non-existence of intestinal lesions, from the extent or seat of the symptoms alone, the physician should not venture to pronounce definitively on the fact of poisoning.

The result of Mr. Brodie's experiments on brutes, teaches that the inflammations of the intestines and stomach are more severe when the poison has been applied to an external wound, than when it has been thrown into the stomach itself. The best remedies against this poison in the stomach are copious draughts of bland liquids of a mucilaginous consistence to inviscate the powder, so as to procure its complete ejection by vomiting. Sulphuretted hydrogen condensed in water, is the only direct antidote to its virulence; Orfila having found, that when dogs were made to swallow that liquid, after getting a poisonous dose of arsenic, they recovered, though their œsophagus was tied to prevent vomiting; but when the same dose of poison was administered in the same circumstances, without the sulphuretted water, that it proved fatal. When the *viscera* are to be subjected after death to chemical investigation, a ligature ought to be thrown round the œsophagus and the beginning of the colon, and the intermediate stomach and intestines removed. Their liquid contents should be emptied into a basin; and thereafter a portion of hot water introduced into the stomach, and worked thoroughly up and down this *viscus*, as well as the intestines.

After filtration, a portion of the liquid should be concentrated by evaporation in a porcelain capsule, and then submitted to the proper reagents above described. We may also endeavour to extract from the stomach by digestion in boiling water, with a little ammonia, the arsenical impregnation, which has been sometimes known to adhere in minute particles with wonderful pertinacity. This precaution ought therefore to be attended to. The heat will dissipate the excess of ammonia in the above operation; whereas by adding potash or soda, as prescribed by the German chemists, we introduce animal matter in alkaline solution, which complicates the investigation.

The matters rejected from the patient's bowels before death should not be neglected. These, generally speaking, are best treated by cautious evaporation to dryness; but we must beware of heating the residuum to 400°, since at that temperature, and perhaps a little under it, the arsenious acid itself sublimes.

Vinegar, hydroguretted alkaline sulphurets, and oils, are of no use as counterpoisons. Indeed, when the arsenic exists in substance in the stomach, even sulphuretted hydrogen water is of no avail, however effectually it neutralizes an arsenious solution. Sirups, linseed tea, decoction of mallows, or tragacanth, and warm milk should be administered as copiously as possible, and vomiting provoked by tickling the fauces with a feather. Clysters of a similar nature may be also employed. Many persons have escaped death by having taken the poison mixed with rich soups; and it is well known, that when it is prescribed as a medicine, it acts most beneficially when taken soon after a meal. These facts have led to the prescription of butter and oils, the use of which is, however, not advisable, as they screen the arsenical particles from more proper menstrua, and even appear to aggravate its virulence. Morgagni, in his great work on the seats and causes of disease, states, that at an Italian feast, the dessert was purposely sprinkled over with arsenic instead of flour. Those of the guests who had previously ate and drank little speedily perished; those who had their stomachs well filled, were saved by vomiting. He also mentions the case of three children who ate a vegetable soup poisoned with arsenic. One of them, who took only two spoonsfull, had no vomiting, and died; the other two, who had eaten the rest, vomited, and got well. Should the poisoned patient be incapable of vomiting, a tube of caoutchouc, capable of being attached to a syringe, may be had recourse to. The tube first serves to introduce the drink, and to withdraw it after a few instants.

The following tests of arsenic and corrosive sublimate have been lately proposed by Brugnatelli: Take the starch of wheat boiled in water until it is of a proper consistence, and recently prepared; to this add a sufficient quantity of iodine to make it of a blue colour; it is afterwards to be diluted with pure water until it becomes of a beautiful azure. If to this, some drops of a watery solution of arsenic be added, the colour changes to a reddish hue, and finally vanishes. The solution of corrosive sublimate poured into iodine and starch, produces almost the same change as arsenic; but if to the fluid acted on by the arsenic we add some drops of sulphuric acid, the original blue colour is restored with more than its original brilliancy, while it does not restore the colour to the corrosive sublimate mixture.*

Acid (Benzoic). This acid was first described in 1608, by Blaise de Vigenere, in his Treatise on Fire and Salt, and has been generally known since by the name of flowers of benjamin or benzoin, because it was obtained by sublimation from the resin of this name. As it is still most commonly procured from this substance, it has preserved the epithet of benzoic, though known to be a peculiar acid, obtainable not from benzoin alone, but from different vegetable balsams, vanello, cinnamon, ambergris, the urine of children, frequently that of adults, and always, according to Fourcroy and Vauquelin, though Giese denies this, that of quadrupeds living on grass and hay, particularly the camel, the horse, and the cow. There is reason to conjecture that many vegetables, and among them some of the grasses, contain it, and that it passes from them into the urine. Fourcroy and Vauquelin found it combined with potash and lime in the liquor of dunghills, as well as in the urine of the quadrupeds above mentioned; and they strongly suspect it to exist in the anthoxanthum odoratum, or sweet-scented vernal grass, from which hay principally derives its fragrant smell. Giese, however, could find none either in this grass or in oats.

The usual method of obtaining it affords a very elegant and pleasing example of the chemical process of sublimation. For this purpose a thin stratum of powdered benzoin is spread over the bottom of a glazed earthen pot, to which a tall conical paper covering is fitted: gentle heat is then to be applied to the bottom of the pot, which fuses the benzoin, and fills the apartment with a fragrant smell, arising from a portion of essential oil and acid of benzoin, which are dissipated into the air; at the same time the acid itself rises very suddenly in the paper head, which may be occasionally inspected at the top, though with some little care, because the fumes will excite coughing. This saline sublimate is condensed in the form of long needles, or straight filaments of a white colour, crossing each other in all directions. When the acid ceases to rise, the cover may be changed, a new one applied, and the heat raised: more flowers of a yellowish colour will then rise, which require a second sublimation to deprive them of the empyreumatic oil they contain.

The sublimation of the acid of benzoin may be conveniently performed by substituting an inverted earthen pan instead of the paper cone. In this case the two pans should be made to fit, by grinding on a stone with sand, and they must be luted together with paper dipped in paste. This method seems preferable to the other, where the presence of the operator is required elsewhere; but the paper head can be more easily inspected and changed. The heat applied must be very gentle, and the vessels ought not to be separated till they have become cool.

The quantity of acid obtained in these methods differs according to the management, and probably also from difference of purity, and in other respects of the resin itself. It usually amounts to no more than about one-eighth part of the whole weight. Indeed Scheele says, not more than a tenth or twelfth. The whole acid of benzoin is obtained with greater certainty in the humid process of Scheele: this consists in boiling the powdered resin with lime-water, and afterwards separating the lime by the addition of muriatic acid. Twelve ounces of water are to be poured upon four ounces of slaked lime; and, after the ebullition is over, eight pounds, or ninety-six ounces, more of water are to be added; a pound of finely powdered benzoin being then put into a tin vessel, six ounces of the lime-water are to be added, and mixed well with the powder; and afterwards the rest of the lime-water in the same gradual manner, because the benzoin would coagulate into a mass, if the whole were added at once. This mixture must be gently boiled for half an hour with constant agitation, and afterwards suffered to cool and subside during an hour. The supernatant liquor must be decanted, and the residuum boiled with eight pounds more of lime-water; after which the same process is to be once more repeated: the remaining powder must be edulcorated on the filter by affusions of hot water. Lastly, all the decoctions, being mixed together, must be evaporated to two pounds, and strained into a glass vessel.

This fluid consists of the acid of benzoin combined with lime. After it is become cold, a quantity of muriatic acid must be added, with constant stirring, until the fluid tastes a little sourish. During this time the last-mentioned acid unites with the lime, and forms a soluble salt, which remains suspended, while the less soluble acid of benzoin, being disengaged, falls to the bottom in powder. By repeated affusions of cold water upon the filter, it may be deprived of the muriate of lime and muriatic acid, with which it may happen to be mixed. If it be required to have a shining appearance, it may be dissolved in a small quantity of boiling water, from which it will separate in silky filaments by cooling. By this process the benzoic acid may be procured from other substances, in which it exists.

* Mr. Hatchett has shown, that by digesting benzoin in hot sulphuric acid, very beautiful crystals are sublimed. This is perhaps the best process for extracting the acid. If we concentrate the urine of horses or cows, and pour muriatic acid into it, a copious precipitate of benzoic acid takes place. This is the cheapest source of it.*

As an economical mode of obtaining this acid, Fourcroy recommends the extraction of it from the water that drains from dunghills, cowhouses, and stables, by means of the muriatic acid, which decomposes the benzoate of lime contained in them, and separates the benzoic acid, as in Scheele's process. He confesses the smell of the acid thus obtained differs a little from that of the acid extracted from benzoin; but this, he says, may be remedied, by dissolving the acid in boiling water, filtering the solution, letting it cool, and thus suffering the acid to crystallize, and repeating this operation a second time.

Mr. Accum found the benzoic acid which he obtained from vanello-pods contaminated with a yellow colouring matter, from which it could not be freed by repeated solutions and crystallizations; but by boiling with charcoal powder, the acid was rendered perfectly pure.

The acid of benzoin is so inflammable, that it burns with a clear yellow flame without the assistance of a wick. The sublimed flowers in their purest state, as white as ordinary writing-paper, were fused into a clear transparent yellowish fluid, at the two hundred-and-thirtieth degree of Fahrenheit's thermometer, and at the same time began to rise in sublimation. It is probable that a heat somewhat greater than this may be required to separate it from the resin. It is strongly disposed to take the crystalline form in cooling. The concentrated sulphuric and nitric acids dissolve this concrete acid, and it is again separated, without alteration, by adding water. Other acids dissolve it by the assistance of heat, from which it separates by cooling, unchanged. It is plentifully soluble in ardent spirit, from which it may likewise be separated by diluting the spirit with water. It readily dissolves in oils, and in melted tallow. If it be added in a small proportion to this last fluid, part of the tallow congeals before the rest, in the form of white opaque clouds. If the quantity of acid be more considerable, it separates in part by cooling, in the form of needles or feathers. It did not communicate any considerable degree of hardness to the tallow, which was the object of this experiment. When the tallow was heated nearly to ebullition, it emitted fumes which affected the respiration, like those of the acid of benzoin, but did not possess the peculiar and agreeable smell of that substance, being probably the sebacic acid. A stratum of this tallow, about one-twentieth of an inch thick, was fused upon a plate of brass, together with other fat substances, with a view to determine its relative disposition to acquire and retain the solid state. After it had cooled it was left upon the plate, and, in the course of some weeks, it gradually became tinged throughout of a bluish green colour. If this circumstance be not supposed to have arisen from a solution of the copper during the fusion, it seems a remarkable instance of the mutual action of two bodies in the solid state, contrary to that axiom of chemistry which affirms, that bodies do not act on each other, unless one or more of them be in the fluid state. Tallow itself, however, has the same effect.

Pure benzoic acid is [illegible] the form of a light powder, evidently crystallized in fine needles, the figure of which is difficult to be determined from their smallness. It has a white and shining appearance; but when contaminated by a portion of volatile oil, is yellow or brownish. It is not brittle as might be expected from its appearance, but has rather a kind of ductility and elasticity, and, on rubbing in a mortar, becomes a sort of paste. Its taste is acrid, hot, acidulous, and bitter. It reddens the infusion of litmus, but not sirup of violets. It has a peculiar aromatic smell, but not strong unless heated. This, however, appears not to belong to the acid; for Mr. Giese informs us, that on dissolving the benzoic acid in as little alcohol as possible, filtering the solution, and precipitating by water, the acid will be obtained pure, and void of smell, the odorous oil remaining dissolved in the spirit. Its specific gravity is 0.667. It is not perceptibly altered by the air, and has been kept in an open vessel twenty years without losing any of its weight. None of the combustible substances have any effect on it; but it may be refined by mixing it with charcoal powder and subliming, being thus rendered much whiter and better crystallized. It is not very soluble in water. Wenzel and Lichtenstein say four hundred parts of cold water dissolve but one, though the same quantity of boiling water dissolves twenty parts, nineteen of which separate on cooling.

The benzoic acid unites without much difficulty with the earthy and alkaline bases.

The benzoate of barytes is soluble, crystallizes tolerably well, is not affected by exposure to the air, but is decomposable by fire, and by the stronger acids. That of lime is very soluble in water, though much less in cold than in hot, and crystallizes on cooling. It is in like manner decomposable by the acids and by barytes. The benzoate of magnesia is soluble, crystallizable, a little deliquescent, and more decomposable than the former. That of alumina is very soluble, crystallizes in dendrites, is deliquescent, has an acerb and bitter taste, and is decomposable by fire, and even by most of the vegetable acids. The benzoate of potash crystallizes on cooling in little compacted needles. All the acids decompose it, and the solution of barytes and lime form with it a precipitate. The benzoate of soda is very crystallizable, very soluble, and not deliquescent like that of potash, but it is decomposable by the same means. It is sometimes found native in the urine of graminivorous quadrupeds, but by no means so abundantly as that of lime. The benzoate of ammonia is volatile, and decomposable by all the acids and all the bases. The solutions of all the benzoates, when drying on the sides of a vessel wetted with them, form dendritical crystallizations.

Trommsdorf found in his experiments, that benzoic acid united readily with metallic oxides.

From the chemical properties of this acid, it appears to differ from the other vegetable acids in the nature and properties of the principles that constitute its radical. Its odour, volatility, combustibility, great solubility in alcohol, and little solubility in water, formerly occasioned it to be considered as an oily acid; and have led modern chemists to conceive, that it contains a large quantity of hydrogen in its composition, and that it is in the superabundance of this combustible principle its difference from the other vegetable acids consists. Its solubility in the powerful acids, and its subsequent separation, indicate that its principles are not easily separable from each other. Attempts have been made to decompose it by repeated abstraction of nitric acid; the nitric acid rises first, scarcely altered except toward the end of the process, when nitrous gas comes over; and the acid of benzoin is afterwards sublimed with little alteration. By repeating the process, however, it is said to become more fixed, and at length to afford a few drops of an acid resembling the oxalic in its properties.

* Berzelius, from the benzoate of lead, deduces the weight of the prime equivalent of benzoic acid to be 14.893; and it consists per cent of 5.16 hydrogen, 74.41 carbon, and 20.43 oxygen.

The benzoates are all decomposable by heat, which, when it is slowly applied, first separates a portion of the acid in a vapour, that condenses in crystals. The soluble benzoates are decomposed by the powerful acids, which separate their acid in a crystalline form. The benzoate of ammonia has been proposed by Berzelius as a reagent for precipitating red oxide of iron from perfectly neutral solutions. According to my experiments, 21.3 of ammonia take 15.7 of crystallized benzoic acid for neutralization.*

The benzoic acid is occasionally used in medicine, but not so much as formerly; and enters into the composition of the camphorated tincture of opium of the London college, heretofore called paregoric elixir.

* **Acid (Boletic).** An acid extracted from the expressed juice of the *boletus pseudo-igniarius* by M. Braconnot. This juice concentrated to a sirup by a very gentle heat, was acted on by strong alcohol. What remained was dissolved in water. When nitrate of lead was dropped into this solution, a white precipitate fell, which, after being well washed with water, was decomposed by a current of sulphuretted hydrogen gas. Two different acids were found in the liquid after filtration and evaporation. One in permanent crystals was boletic acid; the other was a small proportion of phosphoric acid. The former was purified by solution in alcohol, and subsequent evaporation.

It consists of irregular four-sided prisms, of a white colour, and permanent in the air. Its taste resembles cream of tartar; at the temperature of 68° it dissolves in 180 times its weight of water, and in 45 of alcohol. Vegetable blues are reddened by it. Red oxide of iron, and the oxides of silver and mercury, are precipitated by it from their solutions in nitric acid; but lime and barytes waters are not affected. It sublimes when heated, in white vapours, and is condensed in a white powder. *Ann. de Chimie, lxxx.**

Acid (Boracic). The salt composed of this acid and soda, had long been used both in medicine and the arts under the name of borax, when Homberg first obtained the acid separate in 1702, by distilling a mixture of borax and sulphate of iron. He supposed, however, that it was a product of the latter; and gave it the name of *volatile narcotic salt of vitriol, or sedative salt.* Lemery the younger soon after discovered, that it could be obtained from borax equally by means of the nitric or muriatic acid; Geoffroy detected soda in borax; and at length Baron proved by a number of experiments, that borax is a compound of soda and a peculiar acid. Cadet has disputed this; but he has merely shown, that the borax of the shops is frequently contaminated with copper; and Struve and Exchaquet have endeavoured to prove that the boracic and phosphoric acids are the same; yet their experiments only show, that they resemble each other in certain respects, not in all.

To procure the acid, dissolve borax in hot water, and filter the solution; then add sulphuric acid by little and little, till the liquid has a sensibly acid taste. Lay it aside to cool, and a great number of small shining laminated crystals will form. These are the boracic acid. They are to be washed with cold water, and drained upon brown paper.

Boracic acid thus procured is in the form of thin irregular hexagonal scales, of a silvery whiteness, having some resemblance to spermaceti, and the same kind of greasy feel. It has a sourish taste at first, then makes a bitterish cooling impression, and at last leaves an agreeable sweetness. Pressed between the teeth, it is not brittle but ductile. It has no smell; but, when sulphuric acid is poured on it, a transient odour of musk is produced. Its specific gravity in the form of scales is 1.479; after it has been fused, 1.803. It is not altered by light. Exposed to the fire it swells up, from losing its water of crystallization, and in this state is called calcined boracic acid. It melts a little before it is red-hot, without perceptibly losing any water, but it does not flow freely till it is red, and then less than the borate of soda. After this fusion it is a hard transparent glass, becoming a little opaque on exposure to the air, without abstracting moisture from it, and unaltered in its properties, for on being dissolved in boiling water it crystallizes as before. This glass is used in the composition of false gems.

Boiling water scarcely dissolves one fiftieth part, and cold water much less. When this solution is distilled in close vessels, part of the acid rises with the water, and crystallizes in the receiver. It is more soluble in alcohol, and alcohol containing it burns with a green flame, as does paper dipped in a solution of boracic acid.

Neither oxygen gas, nor the simple combustibles, nor the common metals, produce any change upon boracic acid, as far as is at present known. If mixed with finely powdered charcoal, it is nevertheless capable of vitrification; and with soot it melts into a black bitumen-like mass, which however is soluble in water, and cannot easily be burned to ashes, but sublimes in part. With the assistance of a distilling heat it dissolves in oils, especially mineral oils; and with these it yields fluid and solid products, which impart a green colour to spirit of wine. When rubbed with phosphorus it does not prevent its inflammation, but an earthy yellow matter is left behind. It is hardly capable of oxidizing or dissolving any of the metals except iron and zinc, and perhaps copper; but it combines with most of the metallic oxides, as it does with the alkalis, and probably with all the earths, though the greater part of its combinations have hitherto been little examined. It is of great use in analyzing stones that contain a fixed alkali.

* Crystallized boracic acid is a compound of 57 parts of acid and 43 of water. The honour of discovering the radical of *boracic acid*, is divided between Sir H. Davy and M. M. Gay-Lussac and Thenard. The first, on applying his powerful voltaic battery to it, obtained a chocolate-coloured body in small quantity; but the two latter chemists, by acting on it with potassium in equal quantities, at a low red heat, formed boron and subborate of potash. For a small experiment a glass tube will serve, but on a greater scale a copper tube is to be preferred. The potassium and boracic acid, perfectly dry, should be intimately mixed before exposing them to heat. On withdrawing the tube from the fire, allowing it to cool, and removing the cork which loosely closed its mouth, we then pour successive portions of water into it, till we detach or dissolve the whole matter. The water ought to be heated each time. The whole collected liquids are allowed to settle; when, after washing the precipitate till the liquid ceases to affect sirup of violets, we dry the boron in a capsule, and then put it into a phial out of contact of air. Boron is solid, tasteless, inodorous, and of a greenish brown colour. Its specific gravity is somewhat greater than water. The prime equivalent of boracic acid has been inferred from the borate of ammonia, to be about 2.7 or 2.8; oxygen being 1.0; and it probably consists of 2.0 of oxygen + 0.8 of boron. But by M. M. Gay-Lussac and Thenard, the proportions would be 2 of boron to 1 of oxygen.*

The boracic acid has a more powerful attraction for lime, than for any other of the bases, though it does not readily form borate of lime by adding a solution of it to lime-water, or decomposing by lime-water the soluble alkaline borates. In either case an insipid white powder, nearly insoluble, which is the borate of lime, is however precipitated. The borate of barytes is likewise an insoluble, tasteless, white powder.

Bergmann has observed, that magnesia, thrown by little and little into a solution of boracic acid, dissolved slowly, and the liquor on evaporation afforded granulated crystals without any regular form: that these crystals were fusible in the fire without being decomposed; but that alcohol was sufficient to separate the boracic acid from the magnesia. If however some of the soluble magnesian salts be decomposed by alkaline borates in a state of solution, an insipid and insoluble borate of magnesia is thrown down. It is probable, therefore, that Bergmann's salt was a borate of magnesia dissolved in an excess of boracic acid; which acid being taken up by the alcohol, the true borate of magnesia was precipitated in a white powder, and mistaken by him for magnesia.

One of the best known combinations of this acid is the native magnesio-calcareous borate of Kalkberg, near Lunenburg: the *wurfelstein* of the Germans, *cubic quartz* of various mineralogists, and *boracite* of Kirwan. It is of a grayish white colour, sometimes passing into the greenish white, or purplish. Its figure is that of a cube, incomplete on its twelve edges, and at four of its solid angles; the complete and incomplete angles being diametrically opposite to each other. The surfaces generally appear corroded. It strikes fire with steel, and scratches glass. Its specific gravity is 2.566, as determined by M. Westrumb, who found it to be composed of boracic acid 0.68, magnesia 0.1305, lime 0.11; with alumina 0.01, silex 0.02, and oxide of iron 0.0075, all of which he considers as casual. Its most remarkable property, discovered by Haüy, is, that like the tourmalin it becomes electric by heat, though little so by friction; and it has four electric poles, the perfect angles always exhibiting negative electricity, and the truncated angles positive.

Since the component parts of this native salt have been known, attempts have been made to imitate it by art; but no chemist has been able, by mixing lime, magnesia, and boracic acid, to produce any thing but a pulverulent salt, incapable of being dissolved, or exhibited in the crystallized form, and with the hardness of the borate of Kalkberg.

It has lately been denied, however, that this compound is really a triple salt. Vauquelin, examining this substance with Mr. Smith, who had a considerable quantity, found the powder to effervesce with acids; and therefore concluded the lime to be no essential part of the compound. They attempted, by using weak acids much diluted, to separate the carbonate from the borate; but they did not succeed, because the acid attacked the borate likewise, though feebly. M. Stromager having afterwards supplied Vauquelin with some transparent crystals, which did not effervesce with acids, he mixed this powder with muriatic acid, and, when the solution was effected by means of heat, evaporated to dryness to expel the excess of acid. By solution in a small quantity of cold distilled water, he separated most of the boracic acid; and, having diluted the solution, added a certain quantity of oxalate of ammonia, but no sign of the existence of lime appeared. To ascertain that the precipitation of the lime was not prevented by the presence of the small quantity of boracic acid, he mixed with the solution a very small portion of muriate of lime, and a cloudiness immediately ensued through the whole. Hence he infers, that the opacity of the magnesian borate is occasioned by carbonate of lime interposed between its particles, and that the borate in transparent crystals contains none.

The borate of potash is but little known, though it is said to be capable of supplying the place of that of soda in the arts; but more direct experiments are required to establish this effect. Like that, it is capable of existing in two states, neutral and with excess of base, but it is not so crystallizable, and assumes the form of parallelopipeds.

With soda the boracic acid forms two different salts. One, in which the alkali is more than triple the quantity necessary to saturate the acid, is of considerable use in the arts, and has long been known by the name of borax; under which its history and an account of its properties will be given. The other is a neutral salt, not changing the sirup of violets green like the borate with excess of base; differing from it in taste and solubility; crystallizing neither so readily, nor in the same manner; not efflorescent like it; but like it fusible into a glass, and capable of being employed for the same purposes. This salt may be formed by saturating the superabundant soda in borax with some other acid, and then separating the two salts: but it is obviously more eligible, to saturate the excess of soda with an additional portion of the boracic acid itself.

Borate of ammonia forms in small rhomboidal crystals, easily decomposed by fire; or in scales, of a pungent urinous taste, which lose the crystalline form, and grow brown on exposure to the air.

It is very difficult to combine the boracic acid with alumina, at least in the direct way. It has been recommended, for this purpose, to add a solution of borax to a solution of sulphate of alumina; but for this process the neutral borate of soda is preferable, since, if borax be employed, the soda that is in excess may throw down a precipitate of alumina, which might be mistaken for an earthy borate.

The boracic acid unites with silex by fusion, and forms with it a solid and permanent vitreous compound. This borate of silex, however, is neither sapid, nor soluble, nor perceptibly alterable in the air; and cannot be formed without the assistance of a violent heat. In the same manner triple compounds may be formed with silex and borates already saturated with other bases.

The boracic acid has been found in a disengaged state in several lakes of hot mineral waters near Monte Rotondo, Berchiaio, and Castellonuovo in Tuscany, in the proportion of nearly nine grains in a hundred of water, by M. Hoeffer. M. Mascagni also found it adhering to schistus, on the borders of lakes, of an obscure white, yellow, or greenish colour, and crystallized in the form of needles. He has likewise found it in combination with ammonia.

Acid (Camphoric). M. Kosegarten found some years ago, that an acid with peculiar properties was obtained, by distilling nitric acid eight times following from camphor. Bouillon Lagrange has since repeated his experiments, and the following is the account he gives of its preparation and properties.

One part of camphor being introduced into a glass retort, four parts of nitric acid of the strength of 36 degrees are to be poured on it, a receiver adapted to the retort, and all the joints well luted. The retort is then to be placed on a sand-bath, and gradually heated. During the process a considerable quantity of nitrous gas, and of carbonic acid gas, is evolved; and part of the camphor is volatilized, while another part seizes the oxygen of the nitric acid. When no more vapours are extricated, the vessels are to be separated, and the sublimed camphor added to the acid that remains in the retort. A like quantity of nitric acid is again to be poured on this, and the distillation repeated. This operation must be reiterated till the camphor is completely acidified. Twenty parts of nitric acid at 36 are sufficient to acidify one of camphor.

When the whole of the camphor is acidified, it crystallizes in the remaining liquor. The whole is then to be poured out upon a filter, and washed with distilled water, to carry off the nitric acid it may have retained. The most certain indication of the acidification of the camphor is its crystallizing on the cooling of the liquor remaining in the retort.

To purify this acid it must be dissolved in hot distilled water, and the solution, after being filtered, evaporated nearly to half, or till a slight pellicle forms; when the camphoric acid will be obtained in crystals on cooling.

This experiment being too long to be exhibited by the chemical lecturer, its place may be supplied by the following.

A jar is to be filled over mercury with oxygen gas from the chlorate of potash, and a little water passed into it. On the other hand, a bit of camphor and an atom of phosphorus are to be placed in a little cupel; and then one end of a curved tube is to be conveyed under the jar, and the other end under a jar filled with water in the pneumato-chemical apparatus. The apparatus being thus arranged, the phosphorus is to be kindled by means of a red hot iron. The phosphorus inflames, and afterwards the camphor. The flame produced by the camphor is very vivid; much heat is given out; and the jar is lined with a black substance, which gradually falls down, and covers the water standing on the quicksilver in the jar. This is oxide of carbon. At the same time a gas is collected, that has all the characters of carbonic acid. The water contained in the jar is very fragrant, and contains camphoric acid in solution.

The camphoric acid has a slightly acid, bitter taste, and reddens infusion of litmus.

It crystallizes; and the crystals upon the whole resemble those of muriate of ammonia. (Kosegarten says they are parallelopipeds of a snowy whiteness.) It effloresces on exposure to the atmosphere; is not very soluble in cold water; when placed on burning coals, gives out a thick aromatic smoke, and is entirely dissipated; and with a gentle heat melts, and is sublimed. The mineral acids dissolve it entirely. It decomposes the sulphate and muriate of iron. The fixed and volatile oils dissolve it. It is likewise soluble in alcohol, and is not precipitated from it by water; a property that distinguishes it from the benzoic acid. It unites easily with the earths and alkalis.

To prepare the camphorates of lime, magnesia and alumina, these earths must be diffused in water, and crystallized camphoric acid added. The mixture must then be boiled, filtered while hot, and the solution concentrated by evaporation.

The camphorate of barytes is prepared by dissolving the pure earth in water, and then adding crystallized camphoric acid.

Those of potash, soda, and ammonia, should be prepared with their carbonates dissolved in water: these solutions are to be saturated with crystallized camphoric acid, heated, filtered, evaporated, and cooled, by which means the camphorates will be obtained.

If the camphoric acid be very pure, they have no smell; if it be not, they have always a slight smell of camphor.

The camphorates of alumina and barytes leave a little acidity on the tongue; the rest have a slightly bitterish taste.

They are all decomposed by heat; the acid being separated and sublimed, and the base remaining pure; that of ammonia excepted, which is entirely volatilized.

If they be exposed to the blow-pipe, the acid burns with a blue flame: that of ammonia gives first a blue flame; but toward the end it becomes red.

The camphorates of lime and magnesia are little soluble, the others dissolve more easily.

The mineral acids decompose them all. The alkalis and earths act in the order of their affinity for the camphoric acid; which is, lime, potash, soda, barytes, ammonia, alumina, magnesia.

Several metallic solutions, and several neutral salts, decompose the camphorates; such as the nitrate of barytes, most of the calcareous salts, &c.

The camphorates of lime, magnesia, and barytes, part with their acid to alcohol.—*Lagrange's Manuel d'un Cours de Chimie.*

Acid (Carbonic). This acid, being a compound of carbon and oxygen, may be formed by burning charcoal; but as it exists in great abundance ready formed, it is not necessary to have recourse to this expedient. All that is necessary is to pour sulphuric acid, diluted with five or six times its weight of water, on common chalk, which is a compound of carbonic acid and lime. An effervescence ensues; carbonic acid is evolved in the state of gas, and may be received in the usual manner.

As the rapid progress of chemistry during the latter part of the 18th century, was in a great measure owing to the discovery of this acid, it may be worth while to trace the history of it somewhat particularly.

Paracelsus and Van Helmont were acquainted with the fact, that air is extricated from solid bodies during certain processes; and the latter gave to air thus produced the name of gas. Boyle called these kinds of air artificial airs, and suspected that they might be different from the air of the atmosphere. Hales ascertained the quantity of air that could be extricated from a great variety of bodies, and showed that it formed an essential part of their composition. Dr. Black proved, that the substances then called lime, magnesia, and alkalis, were compounds, consisting of a peculiar species of air, and pure lime, magnesia, and alkali. To this species of air he gave the name of fixed air, because it existed in these bodies in a fixed state. This air or gas was afterwards investigated, and a great number of its properties ascertained, by Dr. Priestley. From these properties Mr. Keir first concluded that it was an acid; and this opinion was soon confirmed by the experiments of Bergmann, Fontana, and others. Dr. Priestley at first suspected that this acid entered as an element into the composition of atmospherical air; and Bergmann, adopting the same opinion, gave it the name of aërial acid. Mr. Bewley called it mephitic acid, because it could not be respired without occasioning death; and this name was also adopted by Morveau. Mr. Keir called it calcareous acid; and at last M. Lavoisier, after discovering its composition, gave it the name of carbonic acid gas.

The opinions of chemists concerning the composition of carbonic acid have undergone as many revolutions as its name. Dr. Priestley and Bergmann seem at first to have considered it as an element; and several celebrated chemists maintained that it was the acidifying principle. Afterwards it was discovered to be a compound, and that oxygen gas was one of its component parts. Upon this discovery the prevalent opinion of chemists was, that it consisted of oxygen and phlogiston; and when hydrogen and phlogiston came, according to Mr. Kirwan's theory, to signify the same thing, it was of course maintained that carbonic acid was composed of oxygen and hydrogen: and though M. Lavoisier demonstrated that it was formed by the combination of carbon and oxygen, this did not prevent the old theory from being maintained; because carbon was itself considered as a compound, into which a very great quantity of hydrogen entered. But after M. Lavoisier had demonstrated, that the weight of the carbonic acid produced was precisely equal to the charcoal and oxygen employed; after Mr. Cavendish had discovered, that oxygen and hydrogen when combined did not form carbonic acid, but water, it was no longer possible to doubt that this acid was composed of carbon and oxygen. Accordingly, all farther dispute about it is at an end.

If any thing were still wanting, to put this conclusion beyond the reach of doubt, it was to decompose carbonic acid, and thus to exhibit its component parts by analysis as well as synthesis. This has been actually done by Mr. Tennant. Into a tube of glass he introduced a bit of phosphorus and some carbonate of lime. He then sealed the tube hermetically, and applied heat. Phosphate of lime was formed, and a quantity of charcoal deposited. Now phosphate of lime is composed of phosphoric acid and lime, and phosphoric acid is composed of phosphorus and oxygen. The substances introduced into the tube were phosphorus, lime, and carbonic acid, and the substances found in it were phosphorus, lime, oxygen, and charcoal. The carbonic acid, therefore, must have been decomposed, and it must have consisted of oxygen and charcoal.—This experiment was repeated by Doctor Pearson, who ascertained that the weight of the oxygen and charcoal together was equal to that of the carbonic acid which had been introduced; and in order to show that it was the carbonic acid which had been decomposed, he introduced pure lime and phosphorus; and, instead of phosphate of lime and carbon, he got nothing but phosphuret of lime. These experiments were also confirmed by Fourcroy, Vauquelin, Sylvestre, and Brongniart. Count Mussin-Puschkin too boiled a solution of carbonate of potash on purified phosphorus, and obtained charcoal. This he considered as an instance of the decomposition of carbonic acid, and as a confirmation of the experiments above related.

Carbonic acid abounds in great quantities in nature, and appears to be produced in a variety of circumstances. It composes $\frac{44}{100}$ of the weight of limestone, marble, calcareous spar, and other natural specimens of calcareous earth, from which it may be extricated either by the simple application of heat, or by the superior affinity of some other acid; most acids having a stronger action on bodies than this. This last process does not require heat, because fixed air is strongly disposed to assume the elastic state. Water, under the common pressure of the atmosphere, and at a low temperature, absorbs somewhat more than its bulk of fixed air, and then constitutes a weak acid. If the pressure be greater, the absorption is augmented. It is to be observed, likewise, that more gas than water will absorb, should be present. Heated water absorbs less; and if water, impregnated with this acid, be exposed on a brisk fire, the rapid escape of the aërial bubbles affords an appearance as if the water were at the point of boiling, when the heat is not greater than the hand can bear. Congelation separates it readily and completely from water; but no degree of cold or pressure has yet exhibited this acid in a dense or concentrated state of fluidity.

Carbonic acid gas is much denser than common air, and for this reason occupies the lower parts of such mines or caverns as contain materials which afford it by decomposition. The miners call it choke-damp. The Grotto del Cano, in the kingdom of Naples, has been famous for ages, on account of the effects of a stratum of fixed air which covers its bottom. It is a cave or hole in the side of a mountain, near the lake Agnano, measuring not more than eighteen feet from its entrance to the inner extremity; where if a dog or other animal that holds down its head be thrust, it is immediately killed by inhaling this noxious fluid.

Carbonic acid gas is emitted in large quantities by bodies in the state of the vinous fermentation, (see FERMENTATION), and on account of its great weight, it occupies the apparently empty space or upper part of the vessels in which the fermenting process is going on. A variety of striking experiments may be made in this stratum of elastic fluid. Lighted paper, or a candle dipped into it, is immediately extinguished; and the smoke remaining in the carbonic acid gas renders its surface visible, which may be thrown into waves by agitation like water. If a dish of water be immersed in this gas, and briskly agitated, it soon becomes impregnated, and obtains the pungent taste of Pyrmont water. In consequence of the weight of the carbonic acid gas, it may be lifted out in a pitcher, or bottle, which, if well corked, may be used to convey it to great distances, or it may be drawn out of a vessel by a cock like a liquid. The effects produced by pouring this invisible fluid from one vessel to another, have a very singular appearance; if a candle or small animal be placed in a deep vessel, the former becomes extinct, and the latter expires in a few seconds, after the carbonic acid gas is poured upon them, though the eye is incapable of distinguishing any thing that is poured. If, however it be poured into a vessel full of air, in the sunshine, its density being so much greater than that of the air, renders it slightly visible by the undulations and streaks it forms in this fluid, as it descends through it.

Carbonic acid reddens infusion of litmus; but the redness vanishes by exposure to the air, as the acid flies off. It has a peculiar sharp taste, which may be perceived over vats in which wine or beer is fermenting, as also in sparkling Champaign, and the brisker kinds of cider. Light passing through it is refracted by it, but does not effect any sensible alteration in it, though it appears, from experiment, that it favours the separation of its principles by other substances. It will not unite with an overdose of oxygen, of which it contains 72 parts in 100, the other 28 being pure carbon. It not only destroys life, but the heart and muscle of animals killed by it lose all their irritability, so as to be insensible to the stimulus of galvanism.

Carbonic acid is dilated by heat, but not otherwise altered by it. It is not acted upon by oxygen, or any of the simple combustibles. Charcoal absorbs it, but gives it out again unchanged, at ordinary temperatures; but when this gaseous acid is made to traverse charcoal ignited in a tube, it is converted into carbonic oxide. Phosphorus is insoluble in carbonic acid gas; but, as already observed, is capable of decomposing it by compound affinity, when assisted by sufficient heat; and Priestley and Cruickshank have shown that iron, zinc, and several other metals, are capable of producing the same effect. If carbonic acid be mixed with sulphuretted, phosphuretted, or carburetted gas, it renders them less combustible, or destroys their combustibility entirely, but produces no other sensible change. Such mixtures occur in various analyses, and particularly in the products of the decomposition of vegetable and animal substances. The inflammable air of marshes is frequently carburetted hydrogen intimately mixed with carbonic acid gas, and the sulphuretted hydrogen gas obtained from mineral waters is very often mixed with it.

Carbonic acid appears from various experiments of Ingenhousz to be of considerable utility in promoting vegetation. It is probably decomposed by the organs of plants, its base furnishing part at least of the carbon that is so abundant in the vegetable kingdom, and its oxygen contributing to replenish the atmosphere with that necessary support of life, which is continually diminished by the respiration of animals and other causes.

* The most exact experiments on the neutral carbonates concur to prove, that the prime equivalent of carbonic acid is 2. 75; and that it consists of one prime of carbon = 0. 75 + 2.0 oxygen. This proportion is most exactly deduced from a comparison of the specific gravities of carbonic acid gas and oxygen; for it is well ascertained that the latter, by its combination with charcoal, and conversion into the former, does not change its volume. Now, 100 cubic inches of oxygen weigh 33.8 gr. and 100 cubic inches of carbonic acid 46.5, showing the weight of combined charcoal in that quantity to be 12.7. But the oxide of carbon contains only half the quantity of oxygen which

carbonic acid does; and we hence infer, that the oxide of carbon consists of one prime of oxygen united to one of carbon. This *a priori* judgment is confirmed by the weight 2.75 deduced from the carbonates, as the prime equivalent of carbonic acid. Therefore we have this proportion:

If 33.8 represent two primes of oxygen, or 2; 12.7 will represent one of carbon. 33.8 : 2. : : 12.7 : 0.751, being, as above, the prime equivalent or first combining proportion of carbon. If the specific gravity of atmospheric air be called 1.0000, that of carbonic acid will be 1.5236.

We have seen that water absorbs about its volume of this acid gas, and thereby acquires a specific gravity of 1.0015. On freezing it, the gas is as completely expelled as by boiling. By artificial pressure with forcing pumps, water may be made to aborb two or three times its bulk of carbonic acid. When there is also added a little potash or soda, it becomes the aërated or carbonated alkaline waters, a pleasant beverage, and not inactive remedy in several complaints, particularly dyspepsia, hiccup, and disorders of the kidneys. Alcohol condenses twice its volume of carbonic acid. The most beautiful analytical experiment with carbonic acid, is the combustion of potassium in it, the formation of potash, and the deposition of charcoal. Nothing shows the power of chemical research in a more favourable light, than the extraction of an invisible gas from Parian marble or crystallized spar, and its resolution by such an experiment into oxygen and carbon; in the proportions above stated, 5 gr. of potassium should be used for 3 cubic inches of gas. If less be employed, the gas will not all be decomposed, but a part will be absorbed by the potash. From the above quantities, 3-8ths of a grain of charcoal will be obtained. If a porcelain tube, containing a coil of fine iron wire, be ignited in a furnace, and if carbonic acid be passed backwards and forwards by means of a full and empty bladder, attached to the ends of the tube, the gas will be converted into carbonic oxide, and the iron will be oxidized.*

In point of affinity for the earths and alkalis, carbonic acid stands apparently low in the scale. Before its true nature was known, its compounds with them were not considered as salts, but as the earths and alkalis themselves, only distinguished by the names of *mild*, or *effervescent*, from their qualities of effervescing with acids, and wanting causticity.

The carbonates are characterized by effervescing with almost all the acids, even the acetic, when they evolve their gaseous acid, which passed into lime water by a tube, deprives it of its taste, and converts it into chalk and pure water.

The carbonate of barytes was formed artificially by Bergman and Scheele in 1776; but Dr. Withering first found it native at Alston Moor in Cumberland in 1783. From this circumstance it has been termed Witherite by Werner. It has been likewise called *aërated heavy spar*, *aërated baroselenite*, *aërated heavy earth* or barytes, *barolite*, &c. Its crystals have been observed to assume four different forms, double six-sided, and double four-sided pyramids; six-sided columns terminated by a pyramid with the same number of faces, and small radiated crystals, half an inch in length, and very thin, appearing to be hexagonal prisms, rounded toward the point. The hexaëdral prism is presumed to be its primitive form. Its specific gravity, when native, is 4.331, when prepared artificially it scarcely exceeds 3.763.

It may be prepared by exposing a solution of pure barytes to the atmosphere, when it will be covered with a pellicle of this salt by absorbing carbonic acid; or carbonic acid may be received into this solution, in which it will immediately form a copious precipitate; or a solution of nitrate or muriate of barytes may be precipitated by a solution of the carbonate of potash, soda, or ammonia. The precipitate, in either of these cases, being well washed, will be found to be very pure carbonate of barytes. It may likewise be procured by decomposing the native sulphate of barytes by the carbonate of potash, or of soda, in the dry way, with the assistance of fire; but in this way the sulphate of barytes is never completely decomposed, and some of it remains mixed with the carbonate.

The carbonate of barytes is soluble only in 4304 times its weight of cold water, and 2304 of boiling water, and this requires a long time; but water saturated with carbonic acid dissolves 1-830th. It is not altered by exposure to the air, but is decomposed by the application of a very violent heat, either in a black lead crucible, or when formed into a paste with charcoal powder. Sulphuric acid, in a concentrated state, or diluted with three or four parts of water, does not separate the carbonic acid with effervescence, unless assisted by heat. Muriatic acid does not act upon it likewise, unless diluted with water, or assisted by heat. And nitric acid does not act upon it at all, unless diluted. It has no sensible taste, yet it is extremely poisonous.

As this salt has lately been found, in large quantities, near Murton in Cumberland, and some other places in the vicinity, it might probably be introduced into manufactures with advantage, as for extracting the bases of several salts.

It is composed of 2.75 parts of acid, and 9.75 of barytes. Its prime equivalent is therefore the sum of these numbers = 12.5.

Carbonate of strontian was first pointed out as distinct from the preceding species by Dr. Crawford in 1790, but Dr. Hope gave the first accurate account of it in the Edinburgh Transactions. It has been found native in Scotland, at Strontian in Argyllshire, and at Leadhills. It is usually in fine striated needles or prisms, that appear to be hexaëdral, semitransparent, and of a white colour slightly tinged with green. It is insipid; requires 1536 parts of boiling water to dissolve it; is not altered by exposure to the air; but when strongly heated in a crucible loses part of its acid; and this decomposition is facilitated by making it into a paste with charcoal powder. When the fire is strongly urged, it attacks the crucible, and melts into a glass, resembling the colour of chrysolite, or pyramidal phosphate of lime. If thrown in powder on well kindled coals, or the flame of a candle, it exhibits red sparks. The same phenomenon occurs, if it be treated with the blow-pipe, which fuses it into an opaque vitreous globule, that falls to powder in the open air. Its specific gravity is only 3.66, in which it differs strikingly from the carbonate of barytes; as it does, in *not* being poisonous, according to the experiments made by Pelletier on various animals.

It consists of 6.5 strontian + 2.75 carbonic acid = 9.25.

Carbonate of lime exists in great abundance in nature, variously mixed with other bodies, under the names of *marble, chalk, limestone, stalactites*, &c. in which it is of more important and extensive use than any other of the salts, except perhaps the muriate of soda. It is often found crystallized, and perfectly transparent. The primitive form of its crystals is the rhomboidal prism, with angles of 101½ and 78½. Its integrant particles have the same form. Beside this, however, many varieties of its crystals have been discovered and described by mineralogists. The specific gravity of the marbles is from 2.65 to 2.85; of the crystallized carbonates, about 2.7; of the stalactites, from 2.32 to 2.47: of the limestones, from 1.39 to 2.72.

It has scarcely any taste; is insoluble in pure water, but water saturated with carbonic acid takes up 1-1500th, though as the acid flies off this is precipitated. It suffers little or no alteration on exposure to the air. When heated it decrepitates, its water flies off, and lastly its acid; but this requires a pretty strong heat. By this process it is burned into lime.

It is composed of 3.56 lime + 2.75 carbonic acid = 6.31; or in 100 parts of 56.4 lime and 43.6 acid.

The carbonate or rather *subcarbonate* of *potash* was long known by the name of *vegetable alkali*. It was also called *fixed nitre, salt of tartar, salt of wormwood*, &c. according to the different modes in which it was procured; and was supposed to retain something of the virtues of the substance from which it was extracted. This error, has been some time exploded, but the knowledge of its true nature is of more recent date.

As water at the usual temperature of the air dissolves rather more than its weight of this salt, we have thus a ready mode of detecting its adulterations in general; and as it is often of consequence in manufactures, to know how much alkali a particular specimen contains, this may be ascertained by the quantity of sulphuric acid it will saturate.

This salt is deliquescent.

It consists of 5.94 potash + 2.75 carbonic acid = 8.69.

The bi-carbonate of potash crystallizes, according to Fourcroy, in square prisms, the apices of which are quadrangular pyramids. According to Pelletier they are tetraëdral rhomboidal prisms, with diedral summits. The complete crystal has eight faces, two hexagons, two rectangles, and four rhombs. It has a urinous but not caustic taste; changes the sirup of violets green; boiling water dissolves five-sixths of its weight, and cold water one-fourth; alcohol, even when hot, will not dissolve more than 1-1200th. Its specific gravity is 2.012.

When it is very pure and well crystallized it effloresces on exposure to a dry atmosphere, though it was formerly considered as deliquescent. The fact is, that the common salt of tartar of the shops is a compound of this carbonate and pure potash; the latter of which, being very deliquescent, attracts the moisture of the air till the whole is dissolved. From its smooth feel, and the manner in which it was prepared, the old chemists called this solution *oil of tartar per deliquium*.

The bi-carbonate of potash melts with a gentle heat, loses its water of crystallization, amounting to $\frac{9}{100}$, and gives out a portion of its carbonic acid; though no degree of heat will expel the whole of the acid. Thus, as the carbonate of potash is always prepared by incineration of vegetable substances, and lixiviation, it must be in the intermediate state; or that of a carbonate with excess of alkali: and to obtain the true carbonate we must saturate this salt with carbonic acid, which is best done by passing the acid in the state of gas through a solution of the salt in twice its weight of water; or, if we want the potash pure, we must have recourse to lime, to separate that portion of acid which fire will not expel.

Another mode, recommended by Berthollet, and which may be of use on some occasions, is to add solid carbonate of ammonia to a solution of potash not saturated, and distil the mixture: when the ammonia may be obtained in the form of gas, or caustic liquor, while the carbonate crystallizes in the retort.

The bi-carbonate usually called supercarbonate by the apothecaries, consists of 2 primes of carbonic acid = 5.500, 1 of potash = 5.940, and 1 of water = 1.125, in all 12.565.

The carbonate of soda has likewise been long known, and distinguished from the preceding by the name of *mineral alkali*. In commerce it is usually called *barilla* or *soda*; in which state, however, it always contains of a mixture of earthy bodies and usually common salt. It may be purified, by dissolving it in a small portion of water, filtering the solution, evaporating at a low heat, and skimming off the crystals of muriate of soda as they form on its surface. When these cease to form, the solution may be suffered to cool, and the carbonate of soda will crystallize. To obtain this salt perfectly pure Klaproth dissolves common carbonate of soda in water, and saturates this solution with nitric acid, taking care that the acid is a little in excess. He then separates the sulphuric acid by nitrate of barytes, and the muriatic acid by nitrate of silver. The fluid thus purified he evaporates to dryness, fuses the nitrate of soda obtained, and decomposes it by detonation with charcoal. He then lixiviates the residue, and crystallizes the carbonate of soda. If it be adulterated with potash, tartaric acid will form a precipitate in a pretty strong solution of it.

It is found abundantly in nature. In Egypt, where it is collected from the surface of the earth, particularly after the desiccation of temporary lakes, it has been known from time immemorial by the name of *nitrum*, *natron*, or *natrum*. This it has been proposed to retain; and accordingly the London college has adopted the term *natron*. Dr. Bostock of Liverpool lately found, that the efflorescence, which copiously covered the decaying parts of the plaster of the salt water baths in that town, consisted of carbonate of soda. A carbonate of soda exported from Tripoli, which is called *Trona* from the name of the place where it is found, and analyzed by Klaproth, contained of soda 37 parts, carbonic acid 38, water of crystallization 22.5, sulphate of soda 2. This does not effloresce. A great deal is prepared in Spain by incinerating the maritime plant salsola; and it is manufactured in this country, as well as in France, from different species of sea-weeds. It is likewise found in mineral waters; and also in some animal fluids.

It crystallizes in irregular or rhomboidal decaëdrons, formed by two quadrangular pyramids, truncated very near their bases. Frequently it exhibits only rhomboidal laminæ. Its specific gravity is 1.3591. Its taste is urinous, and slightly acrid, without being caustic. It changes blue vegetable colours to a green. It is soluble in less than its weight of boiling water, and twice its weight of cold. It is one of the most efflorescent salts known, falling completely to powder in no long time. On the application of heat it is soon rendered fluid from the great quantity of its water of crystallization; but is dried by a continuance of the heat, and then melts. It is somewhat more fusible than the carbonate of potash, promotes the fusion of earths in a greater degree, and forms a glass of better quality. Like that, it is very tenacious of a certain portion of its carbonic acid. It consists in its dry state of 3.94 soda, + 2.75 acid, = 6.69.

* But the crystals contain 10 prime proportions of water. They are composed of 22 soda, + 15.3 carbonic acid, + 62.7 water in 100 parts, or of 1 prime of soda = 3.94, 1 of carb. acid = 2.75, and 10 of water = 11.25, in whole 17.94.

The bi-carbonate of soda may be prepared by saturating the solution of the preceding salt with carbonic acid gas, and then evaporating with a very gentle heat to dryness, when a white irregular saline mass is obtained. The salt is not crystallizable. Its constituents are 3.94 soda, + 5.50 carb. acid, + 1.125 water, = 10.565; or in 100 parts 37.4 soda, + 52 acid, + 10.6 water. The intermediate native compound, the African trona, consists, according to Mr. R. Phillips, of 3 carbonic acid, + 2 soda, + 4 water; or in 100 parts 38 soda, + 40 acid, + 22 water.* See the article Soda.

The carbonate of magnesia, in a state of imperfect saturation with the acid, has been used in medicine for some time under the simple name of magnesia. It is prepared by precipitation from the sulphate of magnesia by means of carbonate of potash. Equal parts of sulphate of magnesia and carbonate of potash, each dissolved in its own weight of boiling water, are filtered and mixed together hot; the sulphate of potash is separated by copious washing with water; and the carbonate of magnesia is then left to drain, and afterwards spread thin on paper, and carried to the drying stove. When once dried it will be in friable white cakes, or a fine powder.

Another mode of preparing it in the

grate will be found under the article Ammonia.

To obtain carbonate of magnesia saturated with acid, a solution of sulphate of magnesia may be mixed cold with a solution of carbonate of potash; and at the expiration of a few hours, as the superfluous carbonic acid that held it in solution flies off, the carbonate of magnesia will crystallize in very regular transparent prisms of six equal sides. It may be equally obtained by dissolving magnesia in water impregnated with carbonic acid, and exposing the solution to the open air. Dr. Thomson says, the most regular crystals will be obtained by mixing together 125 parts of sulphate of magnesia and 136 parts of carbonate of soda, both dissolved in water, filtering the solution, and then setting it aside for two or three days.

These crystals soon lose their transparency, and become covered with a white powder. Exposed to the fire in a crucible, they decrepitate slightly, lose their water and acid, fall to powder, and are reduced to one-fourth of the original weight. When the common carbonate is calcined in the great, it appears as if boiling, from the extrication of carbonic acid; a small portion ascends like a vapour, and is deposited in a white powder on the cold bodies with which it comes into contact; and in a dark place, towards the end of the operation, it shines with a bluish phosphoric light. It thus loses half its weight, and the magnesia is left quite pure.

As the magnesia of the shops is sometimes adulterated with chalk, this may be detected by the addition of a little sulphuric acid diluted with 8 or 10 times its weight of water, as this will form with the magnesia a very soluble salt, while the sulphate of lime will remain undissolved. Calcined magnesia should dissolve in this dilute acid without any effervescence.

The crystallized carbonate dissolves in forty-eight times its weight of cold water; the common carbonate requires at least ten times as much, and first forms a paste with a small quantity of the fluid.

Guyton Morveau has lately found the carbonate of magnesia native, near Castel-la-Monte, in a stone considered there as a clay very rich in alumina. It is amorphous, as white as ceruse, and as compact as the hardest chalk; does not sensibly adhere to the tongue; and has no argillaceous smell. Its specific gravity, when all the bubbles of air it contains have escaped, is 2.612. In the fire it lost 0.585 of its weight, and became sufficiently hard to scratch Bohemian glass slightly. On analysis it was found to contain magnesia 26.3, silex 14.2, carbonic acid 46, water 12, iron an inappreciable quantity.

The carbonate of ammonia, once vulgarly known by the name of *volatile sal ammoniac*, and abroad by that of *English volatile salt*, because it was first prepared in this country, was commonly called *mild volatile alkali*, before its true nature was known.

When very pure it is in a crystalline form, but seldom very regular. Its crystals are so small, that it is difficult to determine their figure. Bergmann describes them as acute octaëdrons, the four angles of which are truncated. Romé de Lisle had compressed tetraëdral prisms, terminated by a dièdral summit. Bergmann obtained his by saturating warm water with the salt, stopping the bottle closely, and exposing it to great cold. The crystals commonly produced by sublimation are little bundles of needles, or very slender prisms, so arranged as to represent herborizations, fern leaves, or feathers. The taste and smell of this salt are the same with those of pure ammonia, but much weaker. It turns the colour of violets green, and that of turmeric brown. It is soluble in rather more than twice its weight of cold water, and in its own weight of hot water; but a boiling heat volatilizes it. When pure, and thoroughly saturated, it is not perceptibly alterable in the air; but when it has an excess of ammonia, it softens and grows moist. It cannot be doubted, however, that it is soluble in air; for if left in an open vessel, it gradually diminishes in weight, and its peculiar smell is diffused to a certain distance. Heat readily sublimes, but does not decompose it.

It has been prepared by the destructive distillation of animal substances, and some others, in large iron pots, with a fire increased by degrees to a strong red heat, the aqueous liquor that first comes over being removed, that the salt might not be dissolved in it. Thus we had the *salt of hartshorn*, *salt of soot*, *essential salt of vipers*, &c. If the salt were dissolved in the water, it was called *spirit* of the substance from which it was obtained. Thus, however, it was much contaminated by a fetid animal oil, from which it required to be subsequently purified, and is much better fabricated by mixing one part of muriate of ammonia and two of carbonate of lime, both as dry as possible, and subliming in an earthen retort.

Sir H. Davy has shown that its component parts vary, according to the manner of preparing it. The lower the temperature at which it is formed, the greater the proportion of acid and water. Thus, if formed at the temperature of 300°, it contains more than fifty per cent of alkali; if at 60°, not more than twenty per cent.

* There are three or four definite compounds of carbonic acid and ammonia. The 1st is the solid sub-carbonate of the shops. It consists of 55 carbonic acid, 30

ammonia, and 15 water; or probably of 3 primes carbonic acid, 2 ammonia, and 2 water; in all 14.76 for its equivalent. 2. But M. Gay-Lussac has shown, that when 100 volumes of ammoniacal gas are mixed with 50 of carbonic acid, the two gases precipitate in a solid salt, which must consist by weight of $56\frac{1}{3}$ acid $+43\frac{2}{3}$ alkali, being in the ratio of a prime equivalent of each. 3. When the pungent sub-carbonate is exposed in powder to the air, it becomes scentless by the evaporation of a definite portion of its ammonia. It is then a compound of about 55 or 56 carbonic acid, 21.5 ammonia, and 22.5 water. It may be represented by 2 primes of acid, 1 of ammonia, and 2 of water, = 12. 4. Another compound, it has been supposed, may be prepared by passing carbonic acid through a solution of the sub-carbonate till it be saturated. This, however, may be supposed to yield the same product as the last salt. M. Gay-Lussac infers the neutral carbonate to consist of equal volumes of the two gases, though they will not directly combine in these proportions. This would give 18.1 to 46.5; the very proportions in the scentless salt. For 46.5 : 18.1 : : 55 : 21.42.*

It is well known as a stimulant usually put into smelling-bottles, frequently with the addition of some odoriferous oil.

Fourcroy has found, that an ammoniaco-magnesian carbonate is formed on some occasions. Thus, if carbonate of ammonia be decomposed by magnesia in the moist way, leaving these two substances in contact with each other in a bottle closely stopped, a complete decomposition will not take place, but a portion of this trisalt will be formed. The same will take place, if a solution of carbonate of magnesia in water, impregnated with carbonic acid, be precipitated by pure ammonia; or if ammoniaco-magnesian sulphate, nitrate, or muriate, be precipitated by carbonate of potash or of soda.

The properties of this triple salt are not yet known, but it crystallizes differently from the carbonate of either of its bases, and has its own laws of solubility and decomposition.

The carbonate of glucine has been examined by Vauquelin, and is, among the salts of that earth, that of which he has most accurately ascertained the properties. It is in a white, dull, clotty powder, never dry, but greasy, and soft to the feel. It is not sweet, like the other salts of glucine, but insipid. It is very light, insoluble in water, perfectly unalterable by the air, but very readily decomposed by fire.

A saturated solution of carbonate of ammonia takes up a certain portion of this carbonate, and forms with it a triple salt. This property enabled Vauquelin to separate glucine from alumina, and was one of the means of his distinguishing that earth.

Carbonic acid does not appear to be much disposed to unite with argillaceous earth. Most clays, however, afford a small quantity of this acid by heat; and Fourcroy says, that the fat clays effervesce with acids. The snowy white substance resembling chalk, and known by the name of *lac lunæ*, is found to consist almost wholly of alumina saturated with carbonic acid. A saline substance, consisting of two six-sided pyramids joined at one common base, weighing five or six grains, and of a taste somewhat resembling alum, was produced by leaving an ounce phial of water impregnated with carbonic acid, and a redundancy of alumina, exposed to spontaneous evaporation for some months.

Vauquelin has found, that carbonate of zircone may be formed by evaporating muriate of zircone, redissolving it in water, and precipitating by the alkaline carbonates. He also adds, that it very readily combines so as to form a triple salt with either of the three alkaline carbonates.

* ACID (CASEIC). The name given by Proust to an acid found in cheese, to which he ascribes their flavour.

ACID (CETIC). The name given by M. Chevreul to a supposed peculiar principle of spermaceti, which he has lately found to be the substance he has called Margarine, combined with a fatty matter.*

ACID (CHLORIODIC). See ACID (HYDRIODIC).

ACID (CHLOROCARBONIC). See CHLORINE, and CHLOROCARBONOUS ACID.

ACID (CHLOROCYANIC). See ACID (PRUSSIC).

ACID (CHROMIC). This acid has been examined principally by Vauquelin, who first discovered it, and by count Mussin Puschkin; yet we are better acquainted with it than with the metal that forms its basis. However, as the chromate of iron has lately been found in abundance in the department of Var, in France, and in some other places, we may expect its properties to be more amply investigated, and applied with advantage in the arts, as the chromates of lead and iron are of excellent use in painting and enamelling.

It was extracted from the red lead ore of Siberia, by treating this ore with carbonate of potash, and separating the alkali by means of a more powerful acid. In this state it is a red or orange-coloured powder, of a peculiar rough metallic taste, which is more sensible in it than in any other metallic acid. If this powder be exposed to the action of light and heat, it loses its acidity, and is converted into green oxide of chrome, giving out pure oxygen gas. The chromic acid is the first that has been found to de-oxygenate itself easily by the action of heat, and afford oxygen gas by this simple operation. It appears that several of its properties are owing to the weak adhesion of a part at least of its oxygen. The green oxide of chrome cannot be brought back to the state of an acid, unless its oxygen be restored by treating it with some other acid.

The chromic acid is soluble in water, and crystallizes, by cooling and evaporation, in longish prisms of a ruby red. Its taste is acrid and styptic. Its specific gravity is not exactly known; but it always exceeds that of water. It powerfully reddens the tincture of turnsole.

Its action on combustible substances is little known. If it be strongly heated with charcoal, it grows black, and passes to the metallic state without melting.

Of the acids, the action of the muriatic on it is the most remarkable. If this be distilled with the chromic acid, by a gentle heat, it is readily converted into chlorine. It likewise imparts to it by mixture the property of dissolving gold; in which the chromic resembles the nitric acid. This is owing to the weak adhesion of its oxygen, and it is the only one of the metallic acids that possesses this property.

* The extraction of chromic acid from the French ore, is performed by igniting it with its own weight of nitre in a crucible. The residue is lixiviated with water, which being then filtered, contains the chromate of potash. On pouring into this a little nitric acid and muriate of barytes, an instantaneous precipitate of the chromate of barytes takes place. After having procured a certain quantity of this salt, it must be put in its moist state into a capsule, and dissolved in the smallest possible quantity of weak nitric acid. The barytes is to be then precipitated by very dilute sulphuric acid, taking care not to add an excess of it. When the liquid is found by trial to contain neither sulphuric acid nor barytes, it must be filtered. It now consists of water, with nitric and chromic acids. The whole is to be evaporated to dryness, conducting the heat at the end, so as not to endanger the decomposition of the chromic acid, which will remain in the capsule under the form of a reddish matter. It must be kept in a glass phial well corked.

Chromic acid, heated with a powerful acid, becomes chromic oxide; while the latter, heated with the hydrate of an alkali, becomes chromic acid. As the solution of the oxide is green, and that of the acid yellow, these transmutations become very remarkable to the eye. From Berzelius's experiments on the combinations of the chromic acid with barytes, and oxide of lead, its prime equivalent seems to be 6.5; consisting of 3.5 chromium, and 3.0 oxygen.* See Chromium.

It readily unites with alkalis, and is the only acid that has the property of colouring its salts, whence the name of chromic has been given it. If two parts of the red lead ore of Siberia in fine powder be boiled with one of an alkali saturated with carbonic acid, in forty parts of water, a carbonate of lead will be precipitated, and the chromate remain dissolved. The solutions are of a lemon colour, and afford crystals of a somewhat deeper hue. Those of chromate of ammonia are in yellow laminæ, having the metallic lustre of gold.

The chromate of barytes is very little soluble, and that of lime still less. They are both of a pale yellow, and when heated give out oxygen gas, as do the alkaline chromates.

If the chromic acid be mixed with filings of tin and the muriatic acid, it becomes at first yellowish brown, and afterwards assumes a bluish green colour, which preserves the same shade after desiccation. Ether alone gives it the same dark colour. With a solution of nitrate of mercury, it gives a precipitate of a dark cinnabar colour. With a solution of nitrate of silver it gives a precipitate, which, the moment it is formed, appears of a beautiful carmine colour, but becomes purple by exposure to the light. This combination, exposed to the heat of the blow-pipe, melts before the charcoal is inflamed, and assumes a blackish and metallic appearance. If it be then pulverized, the powder is still purple; but after the blue flame of the lamp is brought into contact with this powder, it assumes a green colour, and the silver appears in globules disseminated through its substance.

With nitrate of copper it gives a chesnut red precipitate. With the solution of sulphate of zinc, muriate of bismuth, muriate of antimony, nitrate of nickel, and muriate of platina, it produces yellowish precipitates, when the solutions do not contain an excess of acid. With muriate of gold it produces a greenish precipitate.

When melted with borax, or glass, or acid of phosphorus, it communicates to it a beautiful emerald green colour.

If paper be impregnated with it, and exposed to the sun a few days, it acquires a green colour, which remains permanent in the dark.

A slip of iron, or tin, put into its solution, imparts to it the same colour.

The aqueous solution of tannin produces a flocculent precipitate of a brown fawn colour.

Sulphuric acid, when cold, produces no effect on it; but when warm it makes it assume a bluish green colour.

Acid (Citric). The juice of lemons,

or limes, has all the characters of an acid of considerable strength; but on account of the mucilaginous matter with which it is mixed, it is very soon altered by spontaneous decomposition. Various methods have been contrived to prevent this effect from taking place, in order that this wholesome and agreeable acid might be preserved for use in long voyages, or other domestic occasions. The juice may be kept in bottles under a thin stratum of oil, which indeed prevents, or greatly retards, its total decomposition; though the original fresh taste soon gives place to one which is much less grateful. In the East Indies it is evaporated to the consistence of a thick extract. If this operation be carefully performed by a very gentle heat, it is found to be very effectual. When the juice is thus heated, the mucilage thickens, and separates in the form of flocks, part of which subsides, and part rises to the surface: these must be taken out. The vapours which arise are not acid. If the evaporation be not carried so far as to deprive the liquid of its fluidity, it may be long preserved in well closed bottles; in which, after some weeks' standing, a farther portion of mucilage is separated, without any perceptible change in the acid.

Of all the methods for preserving lemon-juice, that of concentrating it by frost appears to be the best, though in the warmer climates it cannot conveniently be practised. Lemon-juice, exposed to the air, in a temperature between 50° and 60°, deposites in a few hours a white semitransparent mucilaginous matter, which leaves the fluid, after decantation and filtration, much less alterable than before. This mucilage is not of a gummy nature, but resembles the gluten of wheat in its properties: it is not soluble in water when dried. More mucilage is separated from lemon-juice by standing in closed vessels. If this depurated lemon-juice be exposed to a degree of cold of about seven or eight degrees below the freezing point, the aqueous part will freeze, and the ice may be taken away as it forms; and if the process be continued until the ice begins to exhibit signs of acidity, the remaining acid will be found to be reduced to about one-eighth of its original quantity, at the same time that its acidity will be eight times as intense, as is proved by its requiring eight times the quantity of alkali to saturate an equal portion of it. This concentrated acid may be kept for use, or, if preferred, it may be made into a dry lemonade, by adding six times its weight of fine loaf sugar in powder.

The above processes may be used when the acid of lemons is wanted for domestic purposes, because they leave it in possession of the oils, or other principles, on which its flavour peculiarly depends; but in chemical researches, where the acid itself is required to be had in the utmost purity, a more elaborate process must be used. Boiling lemon-juice is to be saturated with powdered chalk, the weight of which is to be noted, and the powder must be stirred up from the bottom, or the vessel shaken from time to time. The neutral saline compound is scarcely more soluble in water than selenite; it therefore falls to the bottom, while the mucilage remains suspended in the watery fluid, which must be decanted off; the remaining precipitate must then be washed with warm water until it comes off clear. To the powder thus edulcorated, a quantity of sulphuric acid, equal the chalk in weight, and diluted with ten parts of water, must be added, and the mixture boiled a few minutes. The sulphuric acid combines with the earth, and forms sulphate of lime, which remains behind when the cold liquor is filtered, while the disengaged acid of lemons remains dissolved in the fluid. This last must be evaporated to the consistence of a thin sirup, which yields the pure citric acid in little needle-like crystals. It is necessary that the sulphuric acid should be rather in excess, because the presence of a small quantity of lime will prevent the crystallization. This excess is allowed for above.

M. Dize, a skilful apothecary in Paris, who has repeated this process of Scheele on a very extensive scale, asserts, that an excess of sulphuric acid is necessary, not only to obtain the citric acid pure, but to destroy the whole of the mucilage, part of which would otherwise remain, and occasion its spoiling. It is not certain, however, but the sulphuric acid may act on the citric itself, and by decomposing it, produce the charcoal that M. Dize ascribes to the decomposition of mucilage; and if so, the smaller the excess of sulphuric acid the better. He also adds, that to have it perfectly pure it must be repeatedly crystallized, and thus it forms very large and accurately defined crystals in rhomboidal prisms, the sides of which are inclined in angles of 60° and 120°, terminated at each end by tetraëdral summits, which intercept the solid angles. These, however, will not be obtained when operating on small quantities.

Its taste is extremely sharp, so as to appear caustic. Distilled in a retort, part rises without being decomposed; it appears to give out a portion of vinegar; it then evolves carbonic acid gas, and a little carburetted hydrogen; and a light coal remains. It is among the vegetable acids the one which most powerfully resists decomposition by fire.

In a dry and warm air it seems to effloresce; but it absorbs moisture when the air is damp, and at length loses its crystalline form. A hundred parts of this acid are soluble in seventy-five of water at 60°, according to Vauquelin. Though it is less alterable than most other solutions of vegetable acids, it will undergo decomposition when long kept. Fourcroy thinks it probable that it is converted into acetic acid before its final decomposition.

It is not altered by any combustible substance; charcoal alone appears to be capable of whitening it. The most powerful acids decompose it less easily than they do other vegetable acids; but the sulphuric evidently converts it into acetic acid. The nitric acid likewise, according to Fourcroy and Vauquelin, if employed in large quantity, and heated on it a long time, converts the greater part of it into acetic acid, and a small portion into oxalic. Scheele indeed could not effect this; but Westrumb supposes that it was owing to his having used too much nitric acid; for on treating 60 grains of citric acid with 200 of nitric he obtained 30 grains of oxalic acid; with 300 grains of nitric acid he got 15; and with 600 grains no vestige of oxalic acid appeared.

If a solution of barytes be added gradually to a solution of citric acid, a flocculent precipitate is formed, soluble by agitation, till the whole of the acid is saturated. This salt at first falls down in powder, and then collects in silky tufts, and a kind of very beautiful and shining silvery bushes. It requires a large quantity of water to dissolve it.

The citrate of lime has been mentioned already in treating of the mode of purifying the acid.

The citrate of potash is very soluble and deliquescent.

The citrate of soda has a dull saline taste; dissolves in less than twice its weight of water; crystallizes in six-sided prisms with flat summits; effloresces slightly, but does not fall to powder; boils up, swells, and is reduced to a coal on the fire. Lime-water decomposes it, but does not render the solution turbid, notwithstanding the little solubility of citrate of lime.

Citrate of ammonia is very soluble; does not crystallize unless its solution be greatly concentrated; and forms elongated prisms.

Citrate of magnesia does not crystallize. When its solution had been boiled down, and it had stood some days, on being slightly shaken it fixed in one white opaque mass, which remained soft, separating from the sides of the vessel, contracting its dimensions, and rising in the middle like a kind of mushroom.

Its combination with the other earths has not been much examined; and its action upon metals has been little studied. Scheele however found, that it did not precipitate the nitric solutions of metals, as the malic acid does.

All the citrates are decomposed by the powerful acids, which do not form a precipitate with them, as with the oxalates and tartrates. The oxalic and tartaric acids decompose them, and form crystallized or insoluble precipitates in their solutions. All afford traces of acetic acid, or a product of the same nature, on being exposed to distillation: this character exists particularly in the metallic citrates. Placed on burning coals they melt, swell up, emit an empyreumatic smell of acetic acid, and leave a light coal. All of them, if dissolved in water, and left to stand for a time, undergo decomposition, deposite a flocculent mucus which grows black, and leave their bases combined with carbonic acid, one of the products of the decomposition. Before they are completely decomposed, they appear to pass to the state of acetates.

The affinities of the citric acid are arranged by Vauquelin in the following order: barytes, lime, potash, soda, strontian, magnesia, ammonia, alumina. Those for zircone, glucine, and the metallic oxides, are not ascertained.

The citric acid is found in many fruits united with the malic acid; which see for the process of separating them in this case.

* From the composition of the citrate of lead, as determined by Berzelius, it appears that dry citric acid has for its prime equivalent 7.368, compared to yellow oxide of lead 14, and oxygen 1.0. The crystals, according to the same accurate chemist, consist of 79 real acid, and 21 water, in 100 parts. This would make the equivalent of the crystallized acid 9.3. Its ultimate constituents are, by the analysis of

	Hydrog.	Carbon.	Oxyg.
Gay-Lussac and Thenard,	6.330+	33.811+	59.859
Berzelius,	3.800+	41.369+	54.831

Citric acid being more costly than tartaric, may be occasionally adulterated with it. This fraud is discovered, by adding slowly to the acid dissolved in water a solution of sub-carbonate of potash, which will give a white pulverulent precipitate of tartar, if the citric be contaminated with the tartaric acid. When one part of the citric acid is dissolved in 19 of water, the solution may be used as a substitute for lemon-juice. If before solution the crystals be triturated with a little sugar and a few drops of the oil of lemons, the resemblance to the native juice will be complete. It is an antidote against sea scurvy; but the admixture of mucilage and other vegetable matter in the recent fruit of the lemon, has been supposed to render it preferable to the pure acid of the chemist.*

Acid (Chloric). See Acid (Muriatic.)

* Acid (Columbic). The experiments of Mr. Hatchett have proved, that a peculiar mineral from Massachusetts, deposited in the British Museum, consisted of one part of oxide of iron, and somewhat more than three parts of a white coloured substance, possessing the properties of an acid. Its basis was metallic. Hence he named this Columbium, and the acid the Columbic. Dr. Wollaston, by very exact analytical comparisons, proved, that the acid of Mr. Hatchett, was the oxide of the metal lately discovered in Sweden by Mr. Ekeberg, in the mineral yttrotantalite, and thence called tantalum. Dr. Wollaston's method of separating the acid from the mineral is peculiarly elegant. One part of tantalite, five parts of carbonate of potash, and two parts of borax, are fused together in a platina crucible. The mass, after being softened in water, is acted on by muriatic acid. The iron and manganese dissolve, while the columbic acid remains at the bottom. It is in the form of a white powder, which is insoluble in nitric and sulphuric acids, but partially in muriatic. It forms with barytes an insoluble salt, of which the proportions, according to Berzelius, are 24.4 acid, and 9.75 barytes. By oxidizing a portion of the revived tantalum or columbium, Berzelius infers the composition of the acid to be 100 metal and 5.485 oxygen.

Acid (Cyanic). See Acid (Prussic).

Acid (Fluoric). The fusible spar which is generally distinguished by the name of Derbyshire spar, consists of calcareous earth in combination with the acid at present under our consideration. If the pure fluor, or spar, be placed in a retort of lead or silver, with a receiver of the same metal adapted, and its weight of sulphuric acid be then poured upon it, the fluoric acid will be disengaged by the application of a moderate heat. This acid gas readily combines with water; for which purpose it is necessary that the receiver should previously be half filled with that fluid.

* If the receiver be cooled with ice, and no water put in it, then the condensed acid is an intensely active liquid, first procured by M. Gay-Lussac. The best account of it, however, has been given by Sir H. Davy. It has the appearance of sulphuric acid, but is much more volatile, and sends off white fumes when exposed to air. Its specific gravity is only 1.0609. It must be examined with great caution, for when applied to the skin it instantly disorganizes it, and produces very painful wounds. When potassium is introduced into it, it acts with intense energy, and produces hydrogen gas and a neutral salt; when lime is made to act upon it, there is a violent heat excited, water is formed, and the same substance as fluor spar is produced. With water in a certain proportion, its density increases to 1.25. When it is dropped into water, a hissing noise is produced with much heat, and an acid fluid not disagreeable to the taste is formed if the water be in sufficient quantity. It instantly corrodes and dissolves glass.

It appears extremely probable, from all the facts known respecting the fluoric combinations, that fluor spar contains a peculiar acid matter; and that this acid matter is united to lime in the spar, seems evident from the circumstance, that gypsum or sulphate of lime is the residum of the distillation of fluor spar and sulphuric acid. The results of experiments on fluor spar have been differently stated by chemists. Sir H. Davy states, that 100 fluor spar yield 175.2 sulphate of lime; whence we deduce the prime equivalent of fluoric acid to be 1.3260, to lime, 3.56, and oxygen 1.00. From fluate of potash the equivalent comes out for the acid, = 1.2495, potash being reckoned 5.95. Berzelius in his last series of experiments gives from fluate of lime, 1.374 for the equivalent of fluoric acid. The dense fluid obtained in silver vessels, may be regarded as hydrofluoric acid; and, supposing all the water in oil of vitriol transferred to it, would consist of 1.326 or 1.374 acid, + 1.125 water; which is a prime of each.

Dr. Thomson, in his System of Chemistry fifth edition, vol. i. p. 203, deduces the equivalent of fluoric acid from the decomposition of fluate of lime by sulphuric acid, to be 1.0095; and, from the lowness of this number, he afterwards endeavours to prove that fluoric acid cannot be a compound of oxygen with a base. Now taking his own data of 100 parts of fluor spar yielding, according to Sir H. Davy's latest experiments, 175.2 sulphate of lime; and admitting that these contain 73.582 of lime; leaving consequently 26.418 for the proportion of acid in 100 of fluor spar, we shall find 1.3015 to be the equivalent or atom of fluoric acid. For 73.582 : 3.625 : 26.418 : 1.3015, taking his own number 3.625 for the atom of lime. Hence the whole difficulties stated by him in the following passage, page 206, disappear:—"If we suppose fluate of lime to be a compound of fluoric acid and lime, its composition will be, Fluoric acid, 1.0095.

Lime. 3.625

From this we see that the weight of an integrant particle of fluoric acid must be

1.0095. If it be supposed a compound of one atom of oxygen, and one atom of an unknown inflammable basis, then as the weight of an atom of oxygen is 1, the weight of an atom of the inflammable base can be only 0.0095, which is only the thirteenth part of the weight of an atom of hydrogen. On that supposition, fluoric acid would be composed of

Inflammable basis,	1.00
Oxygen,	105.67.

So very light a body, being contrary to all analogy, cannot be admitted to exist without stronger proofs than have hitherto been adduced. On the other hand, if fluor spar be in reality a fluoride of calcium, then its composition will be,

Fluorine,	2.0095
Calcium,	2.625

So that the weight of an atom of fluorine would be 2.0095, or almost exactly twice the weight of an atom of oxygen. This is surely a much more probable supposition than the former."

It is not possible to find a more instructive example than the one now afforded by this systematic chemist, of the danger of prosecuting, on slippery grounds, hypothetical analogies. The atom of fluoric acid, when rightly computed with his own data, is not 1.0095, but 1.3015, and hence none of his consequences need be considered. It may consist of 1 of oxygen combined with 0.3015 of an unknown radical; or there may, for aught we know, be a substance analogous to chlorine and iodine, to be called therefore fluorine, whose prime equivalent will be 2.3015. From the mode in which liquid fluoric acid is produced viz. from a mixture of fluor spar, and oil of vitriol, it may obviously contain water, and may consist, as we have seen, probably of a prime or atom of real acid, and an atom of water. Hence the phenomena occasioned by adding potassium to it, present nothing different from those exhibited by the same metal added to concentrated hydro-nitric or hydro-sulphuric acid. Sir H. Davy indeed has been induced in his last researches to infer, from the action of ammoniacal gas on the liquid fluoric acid, that it contains no water.

On this subject Dr. Thomson has the following aphorism: "When any acid that contains water is combined in this manner with ammoniacal gas, if we heat the salt formed, water is always disengaged. Thus sulphuric acid, or nitric acid, or phosphorous acid, when saturated with ammoniacal gas and heated, give out always abundance of water. But fluate of ammonia, when thus treated, gave out no water. Hence we have no evidence that fluoric acid contains any water."

The whole of this reasoning is visionary. It has been proved in my experimental researches on the ammoniacal salts, inserted in the tenth volume of the Annals of Philosophy, that the sulphate and nitrate of ammonia, in the driest state to which they can be brought by heat, short of their decomposition, contain one atom or prime equivalent of water, which is indeed essential to their very existence, and which water cannot be separated by heat alone. If concentrated oil of vitriol be saturated with dry ammoniacal gas, a solid salt will be obtained, from which heat alone will not separate the proportion of water it contains, and which amounts to 13.6 per cent. A stronger heat will merely separate a portion of the ammonia from the acid, or volatilize both. In the former case the acid retains its atom of water. Hence we see, that no inference whatever can be drawn from the ammoniacal combination with liquid fluoric acid, to negative the probability that it may contain, from the mode of its extraction, combined water, like the sulphuric and nitric acids. The inferences from the analogous actions of potassium on the muriate and fluate of ammonia, are all liable to the same fallacy. If the combined water of the fluoric acid pass into the salt, as with sulphuric acid it undoubtedly does, then hydrogen and fluate of potash ought to result, from the joint actions of potassium and the *hydro*-fluoric acid.

The chocolate powder which is evolved at the positive pole, and the hydrogen at the negative, when liquid fluoric acid was subjected by Sir H. Davy to the voltaic power, can justify no decisive opinion on this intricate research. The mere coating of the platinum wire may as well be regarded as the fluate of platinum, as a fluoride. Nor does the decomposition of the fluates of silver and mercury, when heated in glass vessels with chlorine, seem to prove any thing whatever. The oxygen evolved, is obviously separated from the oxides of silver or mercury when acted on by chlorine; and the dry fluoric acid unites to the silica of the glass, forming silicated fluoric gas, or fluo-silicic acid.

In thus showing the inconclusiveness of Dr. Thomson's four different arguments, to prove that fluoric acid is a compound of an unknown radical, *fluorine*, with hydrogen, and not of an unknown radical, which might be termed fluor, with oxygen; one cannot help, however, expressing a high admiration of Sir H. Davy's experimental researches on fluoric acid, which were published in the second part of the Philosophical Transactions for 1813. He did all which the *existing* resources of science could enable genius and judgment to accomplish. The mystery in which the subject obviously and confessedly remains, must be removed by further investigations, and not by analogical assumptions. These, indeed, by giving resting points to the imagination, of which it becomes found, powerfully tend to obstruct the advancement of truth.

The principal reason for considering fluoric acid as a compound of fluorine with hydrogen, seems on the whole to be the *analogy* of chlorine. But the analogy is incomplete. Certainly it is consonant to the true logic of chemical science to regard chlorine as a simple body, since every attempt to resolve it into simpler forms of matter has failed. But fluorine has not been exhibited in an insulated state like chlorine; and here therefore the analogy does not hold.

With the view of separating its hydrogen, Sir H. Davy applied the power of the great voltaic batteries of the royal Institution to the liquid fluoric acid. "In this case, gas appeared to be produced from both the negative and positive surfaces; but it was probably only the undecompounded acid rendered gaseous, which was evolved at the positive surface; for during the operation the fluid became very hot, and speedily diminished." "In the course of these investigations I made several attempts to detach hydrogen from the liquid fluoric acid, by the agency of oxygen and chlorine. It was not decomposed when passed through a platina tube heated red hot with chlorine, nor by being distilled from salts containing abundance of oxygen, or those containing abundance of chlorine." By the strict rules of chemical logic, therefore, fluoric acid ought to be regarded as a simple body, for we have no evidence of its ever having been decomposed; and nothing but analogy with the other acid bodies has given rise to the assumption of its being a compound.

There is no difficulty in imagining a radical to exist, whose saturating powers are exactly one-third of those of hydrogen; for 0.375 is precisely thrice 0.125, the weight of the prime equivalent of hydrogen; and one-half of 0.750, the equivalent of carbon. Those who are allured by the harmony of numbers, might possibly consider these examples of accordance, as of some value in the discussion.

The marvellous activity of fluoric acid may be inferred from the following remarks of Sir H. Davy, from which also may be estimated in some measure the prodigious difficulty attending refined investigations on this extraordinary substance.

"I undertook the experiment of electrizing pure liquid fluoric acid with considerable interest, as it seemed to offer the most probable method of ascertaining its real nature; but considerable difficulties occurred in executing the process. The liquid fluoric acid immediately destroys glass, and all animal and vegetable substances; it acts on all bodies containing metallic oxides; and I know of no substances which are not rapidly dissolved or decomposed by it, except metals, charcoal, phosphorus, sulphur, and certain combinations of chlorine. I attempted to make tubes of sulphur, of muriates of lead and of copper containing metallic wires, by which it might be electrized, but without success. I succeeded, however, in boring a piece of horn silver in such a manner that I was able to cement a platina wire into it by means of a spirit lamp; and by inverting this in a tray of platina, filled with liquid fluoric acid, I contrived to submit the fluid to the agency of electricity in such a manner, that, in successive experiments, it was possible to collect any elastic fluid that might be produced Operating in this way with a very weak voltaic power, and keeping the apparatus cool by a freezing mixture I ascertained that the platina wire at the positive pole rapidly corroded, and became covered with a chocolate powder; gaseous matter separated at the negative pole, which I could never obtain in sufficient quantities to analyze with accuracy, but it inflamed like hydrogen. No other inflammable matter was produced when the acid was pure." We beg to refer the reader to the Philosophical Transactions for 1813 and 1814; or the 42d and 43d vols. of Tilloch's Magazine, where he will see philosophical sagacity and experimental skill in their utmost variety and vigour, struggling with the most mysterious and intractable powers of matter.

If instead of being distilled in metallic vessels, the mixture of fluor spar and oil of vitriol be distilled in glass vessels, little of the corrosive liquid will be obtained; but the glass will be acted upon, and a peculiar gaseous substance will be produced, which must be collected over mercury. The best mode of procuring this gaseous body is to mix the fluor spar with pounded glass or quartz; and in this case, the glass retort may be preserved from corrosion, and the gas obtained in greater quantities. This gas, which is called silicated fluoric gas, is possessed of very extraordinary properties.

It is very heavy; 100 cubic inches of it weigh 110.77 gr. and hence its sp. gr. is to that of air, as 3.632 is to 1.000. It is about 48 times denser than hydrogen. When brought into contact with water, it instantly deposites a white gelatinous substance, which is hydrate of silica; it produces white fumes when suffered to pass into the atmosphere. It is not affected by any of the common combustible bodies;

but when potassium is strongly heated in it, it takes fire and burns with a deep red light; the gas is absorbed, and a fawn-coloured substance is formed, which yields alkali to water with slight effervescence, and contains a combustible body. The washings afford potash and a salt, from which the strong acid fluid previously described, may be separated by sulphuric acid.

The gas formed by the action of liquid sulphuric acid on a mixture containing silica and fluor spar, the silicated fluoric gas or fluo-silicic acid, may be regarded as a compound of fluoric acid and silica. It affords, when decomposed by solution of ammonia, 61.4 per cent of silica; and hence was at first supposed by Sir H. Davy to consist of two prime proportions of acid = 2.652 and one of silica = 4.066, the sum of which numbers may represent its equivalent = 6.718. One volume of it condenses two volumes of ammonia, and they form together a peculiar saline substance which is decomposed by water. The composition of this salt is easily reconciled to the numbers given as representing silica and fluoric acid, on the supposition that it contains 1 prime of ammonia to 1 of the fluosilicic gas; for 200 cubic inches of ammonia weigh 36.2 gr. and 100 of the acid gas 110.77. Now 36.2 : 2.13 : : 110.77 : 6.52.

Dr. John Davy obtained, by exposing this gas to the action of water, $\frac{152}{1000}$ of its weight of silica; and from the action of water of ammonia he separated $\frac{614}{1000}$ of its weight. Hence 100 cubic inches consist by weight of 68 silica and 42 of unknown fluoric matter, the gas which holds the silica in solution. Sir H. Davy, however, conceives that this gas is a compound of the basis of silica, or silicon, with fluorine, the supposed basis of fluoric acid.

If, instead of glass or silica, the fluor spar be mixed with dry vitreous boracic acid, and distilled in a glass vessel with sulphuric acid, the proportions being one part boracic acid, two fluor spar, and twelve oil of vitriol, the gaseous substance formed is of a different kind, and is called the fluoboric gas. 100 cubic inches of it weigh 73.5 gr. according to Sir H. Davy, which makes its density to that of air as 2.41 is to 1.00; but M. Thenard, from Dr. John Davy, states its density to that of air as 2.371 to 1.000. It is colourless; its smell is pungent, and resembles that of muriatic acid; it cannot be breathed without suffocation; it extinguishes combustion; and reddens strongly the tincture of turnsole. It has no manner of action on glass; but a very powerful one on vegetable and animal matter: It attacks them with as much force as concentrated sulphuric acid, and appears to operate on these bodies by the production of water; for while it carbonizes them, or evolves carbon, they may be touched without any risk of burning. Exposed to a high temperature, it is not decomposed; it is condensed by cold without changing its form. When it is put in contact with oxygen, or air, either at a high or low temperature, it experiences no change, except seizing, at ordinary temperatures, the moisture which these gases contain. It becomes in consequence a liquid which emits extremely dense vapours. It operates in the same way with all the gases which contain hygrometric water. However little they may contain, it occasions in them very perceptible vapours. It may hence be employed with advantage to show whether or not a gas contains moisture.

No combustible body, simple or compound, attacks fluoboric gas, if we except the alkaline metals. Potassium and sodium with the aid of heat, burn in this gas, almost as brilliantly as in oxygen. Boron and fluate of potash, are the products of this decomposition. It might hence be inferred that the metal seizes the oxygen of the boracic acid, sets the boron at liberty, and is itself oxidized and combined with the fluoric acid. According to Sir H. Davy's views, the fluoboric gas being a compound of fluorine and boron, the potassium unites to the former, giving rise to the fluoride of potassium, while the boron remains disengaged.

Fluoboric gas is very soluble in water. Dr. John Davy says, water can combine with 700 times its own volume, or twice its weight at the ordinary temperature and pressure of the air. The liquid has a specific gravity of 1.770. If a bottle containing this gas be uncorked under water, the liquid will rush in and fill it with explosive violence. Water saturated with this gas is limpid, fuming and very caustic. By heat, about one-fifth of the absorbed gas may be expelled; but it is impossible to abstract more. It then resembles concentrated sulphuric acid, and boils at a temperature considerably above 212°. It afterwards condenses altogether, in *striæ*, although it contains still a very large quantity of gas. It unites with the bases, forming salts, called fluoborates, none of which has been applied to any use. The most important will be described under their respective bases.

The 2d part of the Phil. Transactions for 1812, contains an excellent paper by Dr. John Davy on fluosilicic and fluoboric gases, and the combinations of the latter with ammoniacal gas. When united in equal volumes, a pulverulent salt is formed; a second volume of ammonia, however, gives a liquid compound; and a third of ammonia, which is the limit of combination, affords still a liquid; both of them curious on many accounts. "They are," says he, "the first salts that have been observed liquid at the common temperature of the atmosphere. And they are additional facts in support of the doctrine of definite proportions, and of the relation of volumes." The fluosilicic acid also unites to bases forming fluosilicates.

If we regard fluoric acid as capable of combining, like the sulphuric, nitric, and carbonic acids, with the oxidized bases, the weight of its prime equivalent is 1.375; whence all its neutral compounds may be inferred; but if we suppose that it is fluorine alone which unites to the *metallic* bases, then the prime of oxygen must be subtracted from *them* and added to *its* weight, which will make it 2.375. This is exactly like a man taking a piece of money out of the one pocket, and putting it in the other. All the proportions experimentally associated with the compound, remain essentially the same.*

From the remarkable property fluoric acid possesses of corroding glass, it has been employed for etching on it, both in the gaseous state and combined with water; and an ingenious apparatus for this purpose is given by Mr. Richard Knight, in the Philosophical Magazine, vol. xvii. p. 357.

M. Kortum, of Warsaw, having found that some pieces of glass were more easily acted upon by it than others, tried its effect on various stones. Rock crystal, ruby, sapphire. lux sapphire, emerald, oriental garnet, amethyst, chrysolite, aventurine, girasol, a Saxon topaz, a Brazilian topaz burnt, and an opal, being exposed to the fluoric gas at a temperature of 122° F. was not acted upon. Diamond exposed to the vapour on a common German stove for four days, was unaffected. Of polished granite, neither the quarts nor mica appeared to be attacked, but the feldspar was rendered opaque and muddy, and covered with a white powder. Chrysoprase, an opal from Hungary, onyx, a carnelian from Persia, agate, chalcedony, green Siberian jasper, and common flint, were etched by it in twenty-four hours; the chrysoprase near half a line deep, the onyx pretty deeply, the opal with the finest and most regular strokes, and all the rest more or less irregularly. The uncovered part of the brown flint had become white, but was still compact: water, alcohol, and other liquids, rendered the whiteness invisible, but as soon as the flint became dry, it appeared again. The same effect was produced on carnelian, and on a dark brown jasper, if the operation of the acid were stopped, as soon as it had whitened the part exposed, without destroying its texture. A piece of black flint, with efflorescent white spots, and partly covered with the common white crust, being exposed five days to the gas at a heat of about 68° F. was reduced from 103 grains to 91, and rendered white throughout. Some parts of it were rendered friable. White Carrara marble in twenty four hours, at 77°, lost 1-30th of its weight, but the shining surface of its crystallized texture was distinguishable. Black marble was not affected, either in weight or colour, and agate was not attacked. Transparent foliated gypsum fell into white powder on its surface, in a few hours; but this powder was not soluble in dilute nitric acid,—so that the fluoric acid had not destroyed the combination of its principles; but deprived it of its water of crystallization. A striated zeolite, weighing 102 grains, was rendered friable on its surface in forty-eight hours, and weighed only 85½ grains. On being immersed in water, and then dried, it gained 2½ grains, but did not recover its lustre. Barytes of a fibrous texture remained unchanged. A thin plate of Venetian talc, weighing 124 gr. was reduced to 81 grains in forty-eight hours, and had fallen into a soft powder, which floated on water. M. Kortum poured water on the residuum in the apparatus, and the next day the sides were incrusted with small crystalline glittering flakes, adhering in detached masses, which could not be washed off with dilute nitrous acid.

Of the combinations of this acid with most of the bases little is known.

The native fluate of lime, the fluor spar already mentioned, is the most common. It is rendered phosphorescent by heat, but this property gradually goes off, and cannot be produced a second time. With a strong heat it decrepitates. At a heat of 130° of Wedgwood, it enters into fusion in a clay crucible. It is not acted upon by the air, and is insoluble in water. Concentrated sulphuric acid deprives it of the fluoric acid with effervescence, at the common temperature, but heat promotes its action. Besides its use for obtaining this acid, it is much employed in chimney ornaments, and as a flux for some ores and stones.

The fluoric acid takes barytes from the nitric and muriatic, and forms a salt very little soluble, that effloresces in the air.

With magnesia, it precipitates, according to Scheele, in a gelatinous mass. But Bergmann says, that a part remains in solution, and by spontaneous evaporation, shoots on the sides of the vessel into crystalline threads, resembling a transparent mass. The bottom of the vessel affords also crystals in hexagonal prisms, ending in a low pyramid of three rhombs. He adds, that no acid decomposes it in the moist way, and that it is unalterable by the most violent fire.

The fluate of potash is not crystallizable; and if it be evaporated to dryness, it soon deliquesces. Its taste is somewhat acid and saline. It melts with a strong heat, is afterward caustic, and attracts moisture.

This fluate, as well as those of soda and ammonia, are commonly obtained, as Fourcroy conceives, in the state of triple salts, being combined with siliceous earth.

The fluate of soda affords small crystals in cubes and parallelograms, of a bitterish and astringent taste, decrepitating on burning coals, and melting into semitransparent globules with the blowpipe, without losing their acid. It is not deliquescent, and difficultly soluble. The concentrated acids disengage its acid with effervesence.

The fluate of ammonia may be prepared by adding carbonate of ammonia to diluted fluoric acid in a leaden vessel, observing, that there is a small excess of acid. This is a very delicate test of lime.

Fourcroy informs us, that ammonia and magnesia form a triple salt with the fluoric acid.

Scheele observed, that the fluor acid united with alumina into a salt that could not be crystallized, but assumed a gelatinous form. Fourcroy adds, that the solution is always acid, astringent, decomposable and precipitable by all the earthy and alkaline bases, but capable of uniting with silex and the alkalis into various triple salts. A native combination of alumina and soda with fluoric acid, has been found lately in a semitransparent stone from Greenland. See Cryolite.

The affinity of the fluoric acid for silex, has already appeared. If the acid solution of fluate of silex, obtained by keeping the solution of the acid in glass vessels, be evaporated to dryness, the fluoric acid may be disengaged from the solid salt remaining, as Fourcroy informs us, either by the powerful acids, or by a strong heat; and if the solution be kept in a vessel that admits of a slow evaporation, small brilliant crystals, transparent, hard, and apparently of a rhomboidal figure, will form on the bottom of the vessel, as Bergmann found in the course of two years' standing.

Besides the fluor spar and cryolite, in which it is abundant, fluoric acid has been detected in the topaz; in wavellite, in which, however, it is not rendered sensible by sulphuric acid; and in fossil teeth and fossil ivory, though it is not found in either of these in their natural state.

Acids (Ferroprussic and Ferruretted Chyazic). See Acid (Prussic).

Acid (Formic). It has long been known, that ants contain a strong acid, which they occasionally emit; and which may be obtained from the ants, either by simple distillation, or by infusion of them in boiling water, and subsequent distillation of as much of the water as can be brought over without burning the residue. After this it may be purified by repeated rectifications, or by boiling to separate the impurities; or after rectification it may be concentrated by frost.

* This acid has a very sour taste, and continues liquid even at very low temperatures. Its specific gravity is 1.1168 at 68°, which is much denser than acetic acid ever is. Berzelius finds, that the formiate of lead consists of 4.696 acid, and 14 oxide of lead; and that the ultimate constituents of the dry acid are hydrogen 2.84 + carbon 32.40 + oxygen 64.76 = 100.*

We have been informed, that it has been employed among quacks, as a wonderful remedy for the toothach, by applying it to the tooth with the points of the forefinger and thumb.

* **Acid (Fungic).** The expressed juice of the *boletus juglandis*, *boletus pseudo-igniarius*, the *phallus impudicus*, *merulius cantharellus*, or the *peziza nigra*, being boiled to coagulate the albumen, then filtered, evaporated to the consistence of an extract, and acted on by pure alcohol, leaves a substance which has been called by Braconnot *Fungic Acid*. He dissolves that residue in water, added solution of acetate of lead, whence resulted *fungate of lead*, which he decomposed at a gentle heat by dilute sulphuric acid. The evolved fungic acid being saturated with ammonia, yielded a crystallized fungate of ammonia, which he purified by repeated solution and crystallization. From this salt by acetate of lead, and thereafter sulphuric acid as above detailed, he procured the pure fungic acid.

It is a colourless, uncrystallizable, and deliquescent mass, of a very sour taste. The fungates of potash and soda, are uncrystallizable; that of ammonia forms regular six-sided prisms; that of lime is moderately soluble, and is not affected by the air; that of barytes is soluble in 15 times its weight of water, and crystallizes with difficulty; that of magnesia appears in soluble granular crystals. This acid precipitates from the acetate of lead a white flocculent fungate, which is soluble in distilled vinegar. When insulated, it does not affect solution of nitrate of silver; but the fungates decompose this salt.*

Acid (Gallic). This acid is found in different vegetable substances possessing astringent properties, but most abundantly in the excrescences termed galls, or nutgalls, whence it derives its name. It may be obtained by macerating galls in water, filtering, and suffering the liquor to stand exposed to the air. It will grow mouldy, be covered with a thick glutinous pellicle, abundance of glutinous flocks will fall down, and, in the course of two or three months, the sides of the vessel will appear covered with small yellowish crystals, abundance of which will likewise be found on the under surface of the supernatant pellicle. These crystals may be purified by solution in alcohol, and evaporation to dryness.

Or muriate of tin may be added to the infusion of galls, till no more precipitate falls down; the excess of oxide of tin remaining in the solution, may then be precipitated by sulphuretted hydrogen gas, and the liquor will yield crystals of gallic acid by evaporation.

A more simple process, however, is that of M. Fiedler. Boil an ounce of powdered galls in sixteen ounces of water to eight, and strain. Dissolve two ounces of alum in water, precipitate the alumina by carbonate of potash; and, after edulcorating it completely by repeated ablutions, add it to the decoction, frequently stirring the mixture with a glass rod. The next day filter the mixture; wash the precipitate with warm water, till this will no longer blacken sulphate of iron; mix the washings with the filtered liquor, evaporate, and the gallic acid will be obtained in fine needled crystals.

These crystals obtained in any of these ways, however, according to Sir H. Davy, are contaminated with a small portion of extractive matter; and to purify them they may be placed in a glass capsule in a sand heat, and sublimed into another capsule, inverted over this and kept cool. M. Deyeux indeed recommends to procure the acid by sublimation in the first instance; putting the powdered galls into a glass retort, and applying heat slowly and cautiously; when the acid will rise, and be condensed in the neck of the retort. This process requires great care, as, if the heat be carried so far as to disengage the oil, the crystals will be dissolved immediately. The crystals thus obtained are pretty large, laminated, and brilliant.

The gallic acid, placed on a red-hot iron, burns with flame, and emits an aromatic smell, not unlike that of benzoic acid. It is soluble in 20 parts of cold water, and in 3 parts at a boiling heat. It is more soluble in alcohol, which takes up an equal weight if heated, and one-fourth of its weight cold.

* It has an acido-astringent taste, and reddens tincture of litmus. It does not attract humidity from the air.

From the gallate of lead, Berzelius infers the equivalent of this acid to be 8.00. Its ultimate constituents are, hydrogen 5.00 + carbon 56.64 + oxygen 38.36 = 100.

This acid, in its combinations with the salifiable bases, presents some remarkable phenomena. If we pour its aqueous solution by slow degrees into lime, barytes, or strontian water, there will first be formed a greenish white precipitate. As the quantity of acid is increased, the precipitate changes to a violet hue, and eventually disappears. The liquid has then acquired a reddish tint. Among the salts those only of black oxide, and red oxide of iron, are decomposed by the pure gallic acid. It forms a blue precipitate with the first, and a brown with the second. But when this acid is united with tannin, it decomposes almost all the salts of the permanent metals.*

Concentrated sulphuric acid decomposes and carbonizes it; and the nitric acid converts it into malic and oxalic acids.

United with barytes, strontian, lime, and magnesia, it forms salts of a dull yellow colour, which are little soluble, but more so if their base be in excess. With alkalis, it forms salts that are not very soluble in general.

Its most distinguishing characteristic is its great affinity for metallic oxides, so as, when combined with tannin, to take them from powerful acids. The more readily the metallic oxides part with their oxygen, the more they are alterable by the gallic acid. To a solution of gold, it imparts a green hue; and a brown precipitate is formed, which readily passes to the metallic state, and covers the solution with a shining golden pellicle. With nitric solution of silver, it produces a similar effect. Mercury it precipitates of an orange yellow; copper, brown; bismuth, of a lemon colour; lead, white; iron, black. Platina, zinc, tin, cobalt, and manganese, are not precipitated by it.

The gallic acid is of extensive use in the art of dyeing, as it constitutes one of the principal ingredients in all the shades of black, and is employed to fix or improve several other colours. It is well known as an ingredient in ink. See Galls, Dyeing and Ink.

* Acid (Hydrocyanic). See Acid (Prussic).

* Acid (Hydriodic). This acid resembles the muriatic in being gaseous in its insulated state. If four parts of iodine be mixed with one of phosphorus, in a small glass retort, applying a gentle heat, and adding a few drops of water from time to time, a gas comes over, which must be received in the mercurial bath. Its specific gravity is 4.4; 100 cubic inches, therefore, weigh 134.2 grains. It is elastic and invisible, but has a smell somewhat similar to that of muriatic acid. Mercury after some time decomposes it, seizing its iodine, and leaving its hydrogen equal to one-half the original bulk, at li-

berty. Chlorine, on the other hand, unites to its hydrogen, and precipitates the iodine. From these experiments, it evidently consists of vapour of iodine and hydrogen, which combine in equal volumes, without change of their primitive bulk. Its composition by weight, is therefore 8.61 of iodine + 0.0694 hydrogen, which is the relation of their gasiform densities; and if 8.61 be divided by 0.0694, it will give the prime of iodine 124 times greater than hydrogen; and as the prime of oxygen is eight times more than that of hydrogen, on dividing 124 by 8, we have 15.5 for the prime equivalent of iodine; to which, if we add 0.125, the sum 15.625 represents the equivalent of hydriodic acid. The number deduced for iodine, from the relation of iodine to hydrogen in volume, approaches very nearly to 15.621, which was obtained in the other experiments of M. Gay-Lussac. Hydriodic acid is partly decomposed at a red heat, and the decomposition is complete, if it be mixed with oxygen. Water is formed and iodine separated.

M. Gay-Lussac, in his admirable memoir on iodine and its combinations, published in the Ann. de Chimie, vol. xci. says, that the specific gravity he there gives for hydriodic gas, viz. 4.443, must be a little too great, for traces of moisture were seen in the inside of the bottle. In fact, if we take 15.621 as the prime of iodine to oxygen, whose specific gravity is 1.1111; and multiply one-half of this number by 15 621, as he does, we shall have a product of 8.6696, to which adding 0.0694 for the density of hydrogen, we get the sum 8.7390, one-half of which is obviously the density of the hydriodic gas = 4.3695. When the prime of iodine is taken at 15.5, then the density of the gas comes out 4.3.

We can easily obtain an aqueous hydriodic acid very economically, by passing sulphuretted hydrogen gas through a mixture of water and iodine in a Woolfe's bottle. On heating the liquid obtained, the excess of sulphur flies off, and leaves liquid hydriodic acid. At temperatures below 262°, it parts with its water; and becomes of a density = 1.7. At 262° the acid distils over. When exposed to the air, it is speedily decomposed, and iodine is evolved. Concentrated sulphuric and nitric acids also decompose it. When poured into a saline solution of lead, it throws down a fine orange precipitate. With solution of peroxide of mercury, it gives a red precipitate; and with that of silver, a white precipitate insoluble in ammonia. Hydriodic acid may also be formed, by passing hydrogen over iodine at an elevated temperature.

The compounds of hydriodic acid with the salifiable bases may be easily formed, either by direct combination, or by acting on the basis in water, with iodine. The latter mode is most economical. Upon a determinate quantity of iodine, pour solution of potash or soda, till the liquid ceases to be coloured. Evaporate to dryness, and digest the dry salt in alcohol of the specific gravity 0.810, or 0.820. As the iodate is not soluble in this liquid, while the hydriodate is very soluble, the two salts easily separate from each other. After having washed the iodate two or three times with alcohol, dissolve it in water, and neutralize it with acetic acid. Evaporate to dryness, and digest the dry salt in alcohol, to remove the acetate. After two or three washings, the iodate is pure. As for the alcohol containing the hydriodate, distil it off, and then complete the neutralization of the potash, by means of a little hydriodic acid separately obtained. Sulphurous and muriatic acids, as well as sulphuretted hydrogen, produce no change on the hydriodates, at the usual temperature of the air.

Chlorine, nitric acid, and concentrated sulphuric, instantly decompose them, and separate the iodine.

With solution of silver, they give a white precipitate insoluble in ammonia; with the pernitrate of mercury, a greenish yellow precipitate; with corrosive sublimate, a precipitate of a fine orange red, very soluble in an excess of hydriodate; and with nitrate of lead, a precipitate of an orange yellow colour. They dissolve iodine, and acquire a deep reddish brown colour.

Hydriodate of potash, or in the dry state, iodide of potassium, yields crystals like sea-salt, which melt and sublime at a red heat. This salt is not changed by being heated in contact with air. 100 parts of water at 64°, dissolve 143 of it. It consists of 15.5 iodine, and 4.95 potassium.

Hydriodate of soda, called in the dry state *iodide of sodium*, may be obtained in pretty large flat rhomboidal prisms. These prisms unite together with larger [illegible] terminated in echellon, and striated longways, like those of sulphate of soda. This is a true hydriodate, for it contains much water of crystallization. It consists, when dry, of 15.5 iodine + 2.95 sodium.

Hydriodate of barytes crystallizes in fine prisms, similar to muriate of strontian. In its dry state, it consists of 15.5 iodine + 8.7 or 8.75 barium.

The *hydriodates of lime* and *strontian* are very soluble; and the first exceedingly deliquescent.

Hydriodate of ammonia results from the combination of equal volumes of ammoniacal and hydriodic gases; though it is usually prepared by saturating the liquid acid with ammonia. It is nearly as volatile as sal ammoniac; but it is more soluble and more deliquescent. It crystallizes in cubes. From this compound, we may infer the prime of hydriodic acid, from the specific gravity of the hydriodic gas; or having the prime, we may determine the sp. gr. If we call 15.625 its equivalent, then we have this proportion:—As a prime of ammonia, to a prime of hydriodic acid, so is the density of ammoniacal, to that of hydriodic gas.

2.13 : 15.625 : : 0.59 : 4.328.

This would make 100 cubic inches weigh exactly 132 grains.

Hydriodate of magnesia is formed by uniting its constituents together; it is deliquescent, and crystallizes with difficulty. It is decomposed by a strong heat.

Hydriodate of zinc is easily obtained, by putting iodine into water with an excess of zinc, and favouring their action by heat. When dried it becomes an iodide.

All the hydriodates have the property of dissolving abundance of iodine; and thence they acquire a deep reddish brown colour. They part with it on boiling, or when exposed to the air after being dried.*

* Acid (Iodic). When barytes water is made to act on iodine, a soluble hydriodate, and an insoluble iodate of barytes, are formed. On the latter, well washed, pour sulphuric acid equivalent to the barytes present, diluted with twice its weight of water, and heat the mixture. The iodic acid quickly abandons a portion of its base, and combines with the water; but though even less than the equivalent proportion of sulphuric acid has been used, a little of it will be found mixed with the liquid acid. If we endeavour to separate this portion, by adding barytes water, the two acids precipitate together.

The above economical process is that of M. Gay-Lussac; but Sir H. Davy, who is the first discoverer of this acid, invented one more elegant, and which yields a purer acid. Into a long glass tube, bent like the letter L inverted (˥), shut at one end, put 100 grains of chlorate of potash, and pour over it 400 grains of muriatic acid, specific gravity 1.105. Put 40 grains of iodine into a thin long-necked receiver. Into the open end of the bent tube put some muriate of lime, and then connect it with the receiver. Apply a gentle heat to the sealed end of the former. Protoxide of chlorine is evolved, which, as it comes in contact with the iodine, produces combustion, and two new compounds, a compound of iodine and oxygen, and one of iodine and chlorine. The latter is easily separable by heat, while the former remains in a state of purity.

The iodic acid of Sir H. Davy is a white semi-transparent solid. It has a strong acido-astringent taste, but no smell. Its density is considerably greater than that of sulphuric acid, in which it rapidly sinks. It melts, and is decomposed into iodine and oxygen, at a temperature of about 620°. A grain of iodic acid gives out 176.1 grain measures of oxygen gas. It would appear from this, that iodic acid consists of 15.5 iodine, to 5 oxygen. This agrees with the determination of M. Gay-Lussac, obtained from much greater quantities; and must therefore excite admiration at the precision of result derived by Sir H. from the very minute proportions which he used. 176.1 grain measures, are equal to 0.7 of a cubic inch; which, calling 100 cubic inches 33.88, will weigh 0.237 of a grain, leaving 0.763 for iodine. And 0.763 : 0.237 : : 15.5 : 5.0.

Iodic acid deliquesces in the air, and is, of course, very soluble in water. It first reddens, and then destroys the blues of vegetable infusions. It blanches other vegetable colours. By concentration of the liquid acid of Gay-Lussac, it acquires the consistence of sirup. Had not the happy genius of Sir H. Davy produced it in the solid state, his celebrated French rival would have persuaded us to suppose that state impossible. "Hitherto," says M. Gay-Lussac, "iodic acid has only been obtained in combination with water, and it is very probable that this liquid is as necessary as a base, to keep the elements of this acid united, as we see is the case with sulphuric acid, nitric acid," &c. M. Gay-Lussac's Memoir was read to the Institute on the 1st August 1814; and, on the 10th February following, Sir H. dates at Rome his communication to the Royal Society, written before he had seen the French paper. When the temperature of inspissated iodic acid is raised to about 392°, it is resolved into iodine and oxygen. Here we see the influence of water is exactly the reverse of what M. Gay-Lussac assigns to it; for, instead of giving fixity like a base to the acid, it favours its decomposition. The dry acid may be raised to upwards of 600° without being decomposed. Sulphurous acid, and sulphuretted hydrogen immediately separate iodine from it. Sulphuric and nitric acids have no action on it. With solution of silver, it gives a white precipitate, very soluble in ammonia. It combines with all the bases, produces all the iodates which we can obtain by making the alkaline bases act upon iodine in water. It likewise forms with ammonia a salt, which fulminates when heated. Between the acid prepared by M. Gay-Lussac, and that of Sir H. Davy, there is one important difference. The latter being dissolved, may, by evaporation of the water, pass not only to the inspissated sirupy state, but can be made to assume a pasty consistence; and finally, by a stronger heat, yields the solid substance unaltered. When a mixture of it, with charcoal, sulphur, rosin, sugar, or the combustible metals, in a finely divided state, is heated, detonations are produced; and its solution rapidly corrodes all the metals to which Sir H. Davy exposed it, both gold and platinum, but much more intensely the first of these metals.

It appears to form combinations with all the fluid or solid acids which it does not decompose. When sulphuric acid is dropped into a concentrated solution of it in hot water, a solid substance is precipitated, which consists of the acids in combination; for, on evaporating the solution by a gentle heat, nothing rises but water. On increasing the heat in an experiment of this kind, the solid substance formed fused; and on cooling the mixture, rhomboidal crystals formed of a pale yellow colour, which were very fusible, and which did not change at the heat at which the compound of oxygen and iodine decomposes, but sublimed unaltered. When urged by a much stronger heat, it partially sublimed and partially decomposed, affording oxygen, iodine, and sulphuric acid.

With hydro-phosphoric, the compound presents phenomena precisely similar, and they form together a solid, yellow, crystalline combination.

With hydro-nitric acid, it yields white crystals in rhomboidal plates, which, at a lower heat than the preceding acid compounds, are resolved into hydro-nitric acid, oxygen, and iodine. By liquid muriatic acid, the substance is immediately decomposed, and the compound of chlorine and iodine is formed. All these acid compounds redden vegetable blues, taste sour, and dissolve gold and platinum. From these curious researches, Sir H. Davy infers, that M. Gay-Lussac's iodic acid, is a sulpho-iodic acid, and probably a definite compound. However minute the quantity of sulphuric acid made to act on the iodide of barium may be, a part of it is always employed to form the compound acid; and the residual fluid contains both the compound acid and a certain quantity of the original salt.

In treating of hydriodic acid, we have already described the method of forming the iodates, a class of salts distinguished chiefly for their property of deflagrating when heated with combustibles.*

***Acid (Chloriodic).** The discovery of this interesting compound, constitutes another of Sir H. Davy's contributions to the advancement of science. In a communication from Florence to the Royal Society, in March 1814, he gives a curious detail of its preparation and properties. He formed it, by admitting chlorine in excess to known quantities of iodine, in vessels exhausted of air, and repeatedly heating the sublimate. Operating in this way, he found that iodine absorbs less than one-third of its weight of chlorine.

Chloriodic acid is a very volatile substance, and in consequence of its action upon mercury, he was not able to determine the elastic force of its vapour. In the most considerable experiment which he made to determine proportions, 20 grains caused the disappearance of 9.6 cubical inches of chlorine. These weigh 7.296 grains. And 20 : 7.296 :: 15.5 : 5.6, a number certainly not far from 4.5, the prime equivalent of chlorine; and in the very delicate circumstances of the experiment, an approximation not to be disparaged. Indeed, the first result in close vessels, giving less than one-third of the weight of chlorine absorbed, comes sufficiently near 4.5, which is just a little less than one-third of 15.5, the prime equivalent of iodine.

The chloriodic acid formed by the sublimation of iodine in a great excess of chlorine, is of a bright yellow colour; when fused it becomes of a deep orange, and when rendered elastic, it forms a deep orange coloured gas. It is capable of combining with much iodine when they are heated together, its colour becomes, in consequence, deeper, and the chloriodic acid and the iodine rise together in the elastic state. The solution of the chloriodic acid in water, likewise dissolves large quantities of iodine, so that it is possible to obtain a fluid containing very different proportions of iodine and chlorine.

When two bodies so similar in their characters, and in the compounds they form as iodine and chlorine, act upon substances at the same time, it is difficult, Sir H. observes, to form a judgment of the different parts that they play in the new chemical arrangement produced. It appears most probable, that the acid property of the chloriodic compound depends upon the combination of the two bodies; and its action upon solutions of the alkalis and earths may be easily explained, when it is considered that chlorine has a greater tendency than iodine to form double compounds with the metals, and that iodine has a greater tendency than chlorine to form triple compounds with oxygen and the metals.

A triple compound of this kind with sodium may exist in sea water, and would be separated with the first crystals that are formed by its evaporation. Hence, it may exist in common salt. Sir H. Davy ascertained, by feeding birds with bread soaked with water, holding some of it in solution, that it is not poisonous like iodine itself.*

Acid (Hydrothionic). Some of the German chemists distinguish sulphuretted hydrogen by this name, on account of its properties resembling those of an acid.

* Acid (Kinic). A peculiar acid extracted by M. Vauquelin from cinchona. Let a watery extract from hot infusions of the bark [illegible] powder be made. Alcohol removes the resinous part of this extract, and leaves a viscid residue, of a brown colour, which has hardly any bitter taste, and which consists of kinite of lime and a mucilaginous matter. This residue is dissolved in water, the liquor is filtered and left to spontaneous evaporation, in a warm place. It becomes thick like sirup, and then deposites by degrees crystalline plates, sometimes hexahedral, sometimes rhomboidal, sometimes square, and always coloured slightly of a reddish brown. These plates of kinate of lime must be purified by a second crystallization. They are then dissolved in 10 or 12 times their weight of water, and very dilute aqueous oxalic acid is poured into the solution, till no more precipitate is formed. By filtration, the oxalate of lime is separated, and the kinic acid being concentrated by spontaneous evaporation, yields regular crystals. It is decomposed by heat. While it forms a soluble salt with lime, it does not precipitate lead or silver from their solutions. These are characters sufficiently distinctive. The kinates are scarcely known; that of lime constitutes 7 per cent of *cinchona*.*

Acid (Laccic) of Dr. John.

* This chemist made a watery extract of powdered stick lac, and evaporated it to dryness. He digested alcohol on this extract, and evaporated the alcoholic extract to dryness. He then digested this mass in ether and evaporated the etherial solution; when he obtained a sirupy mass of a light yellow colour, which was again dissolved in alcohol. On adding water to this solution a little resin fell. A peculiar acid united to potash and lime remains in the solution, which is obtained free, by forming with acetate of lead an insoluble laccate, and decomposing this with the equivalent quantity of sulphuric acid. Laccic acid crystallizes; it has a wine yellow colour, a sour taste, and is soluble, as we have seen, in water, alcohol, and ether. It precipitates lead and mercury white; but it does not affect lime, barytes, or silver, in their solutions. It throws down the salts of iron white. With lime, soda, and potash, it forms deliquescent salts, soluble in alcohol.*

Acid (Lactic). By evaporating sour whey to one-eighth, filtering, precipitating with lime-water, and separating the lime by oxalic acid, Scheele obtained an aqueous solution of what he supposed to be a peculiar acid, which has accordingly been termed the *lactic*. To procure it separate, he evaporated the solution to the consistence of honey, poured on it alcohol, filtered this solution, and evaporated the alcohol. The residuum was an acid of a yellow colour, incapable of being crystallized, attracting the humidity of the air, and forming deliquescent salts with the earths and alkalis.

Bouillon Lagrange since examined it more narrowly; and from a series of experiments concluded, that it consists of acetic acid, muriate of potash, a small portion of iron probably dissolved in the acetic acid, and an animal matter.

* This judgment of M. Lagrange was afterwards supported by the opinions of MM. Fourcroy and Vauquelin. But since then Berzelius has investigated its nature very fully, and has obtained, by means of a long and often repeated series of different experiments, a complete conviction that Scheele was in the right, and that the lactic acid is a peculiar acid, very distinct from all others. The extract which is obtained when dried whey is digested with alcohol, contains uncombined lactic acid, lactate of potash, muriate of potash, and a proper animal matter. As the elimination of the acid affords an instructive example of chemical research, we shall present it at some detail, from the 2d volume of Berzelius's Animal Chemistry.

He mixed the above alcoholic solution with another portion of alcohol, to which $\frac{1}{75}$ of concentrated sulphuric acid had been added, and continued to add fresh portions of this mixture as long as any saline precipitate was formed, and until the fluid had acquired a decidedly acid taste. Some sulphate of potash was precipitated, and there remained in the alcohol, muriatic acid, lactic acid, sulphuric acid, and a minute portion of phosphoric acid, detached from some bone earth which had been held in solution. The acid liquor was filtered, and afterwards digested with carbonate of lead, which with the lactic acid affords a salt soluble in alcohol. As soon as the mixture had acquired a sweetish taste, the three mineral acids had fallen down in combination with the lead, and the lactic acid remained behind, imperfectly saturated by a portion of it, from which it was detached by means of sulphuretted hydrogen, and then evaporated to the consistence of a thick varnish, of a dark-brown colour, and sharp acid taste, but altogether without smell.

In order to free it from the animal matter which might remain combined with it, he boiled it with a mixture of a large quantity of fresh lime and water, so that the animal substances were precipitated and destroyed by the lime. The lime became yellow brown, and the solution almost colourless, while the mass emitted a smell of soap lees, which disappeared as the boiling was continued. The fluid thus obtained was filtered and evaporated, until a great part of the superfluous lime held in solution was precipitated. A small portion of it was then decomposed by oxalic acid, and carbonate of silver was dissolved in the uncombined lactic acid, until it was fully saturated. With the assistance of the lactate of silver thus obtained, a further quantity of muriatic acid was separated from the lactate of lime, which was then decomposed by pure oxalic acid, free from nitric acid, taking care to leave it in such a state that neither the oxalic acid nor lime water afforded a precipitate. It was then evaporated to dryness, and dissolved again in alcohol, a small portion of oxalate of lime, before retained in union with the acid, now remaining undissolved. The alcohol was evaporated until the mass was no longer fluid while warm; it became a brown clear transparent acid, which was the lactic acid, free from all substances that we have hitherto had reason to think likely to contaminate it.

The lactic acid, thus purified, has a brown yellow colour, and a sharp sour taste, which is much weakened by diluting it with water. It is without smell in the cold, but emits, when heated, a sharp sour smell, not unlike that of sublimed oxalic acid. It cannot be made to crystallize, and does not exhibit the slightest appearance of a saline substance, but dries into a thick and smooth varnish, which slowly attracts moisture from the air. It is very easily soluble in alcohol. Heated in a gold spoon over the flame of a candle, it first boils, and then its pungent acid smell becomes very manifest, but extremely distinct from that of the acetic acid; afterwards it is charred, and has an empyreumatic, but by no means an animal smell. A porous charcoal is left behind, which does not readily burn to ashes. When distilled, it gives an empyreumatic oil, water, empyreumatic vinegar, carbonic acid, and inflammable gases. With alkalis, earths, and metallic oxides, it affords peculiar salts: and these are distinguished by being soluble in alcohol, and in general by not having the least disposition to crystallize, but drying into a mass like gum, which slowly becomes moist in the air.

Lactate of potash is obtained, when the lactate of lime, purified as has been mentioned, is mixed warm with a warm solution of carbonate of potash. It forms, in drying, a gummy, light yellow brown, transparent mass, which cannot easily be made hard. If it is mixed with concentrated sulphuric acid, no smell of acetic acid is perceived; but if the mixture is heated, it acquires a disagreeable pungent smell, which is observable in all animal substances mixed with the sulphuric acid. The extract which is obtained directly from milk, contains this salt; but this affords, when mixed with sulphuric acid, a sharp acid smell, not unlike that of the acetic acid. This, however, depends not on acetic but on muriatic acid, which in its concentrated state introduces this modification into the smell of almost all organic bodies. The pure lactate of potash is easily soluble in alcohol; that which contains an excess of potash, or is still contaminated with the animal matter soluble in alcohol, which is destroyed by the treatment with lime, is slowly soluble, and requires about 14 parts of warm alcohol for its solution. It is dissolved in boiling alcohol more abundantly than in cold, and separates from it, while it is cooling, in the form of hard drops.

The *lactate of soda* resembles that of potash, and can only be distinguished from it by analysis.

Lactate of ammonia. If concentrated lactic acid is saturated with caustic ammonia in excess, the mixture acquires a strong volatile smell, not unlike that of the acetate or formiate of ammonia, which, however, soon ceases. The salt which is left has sometimes a slight tendency to shoot into crystals. It affords a gummy mass, which in the air acquires an excess of acidity. When heated, a great part of the alkali is expelled, and a very acid salt remains, which deliquesces in the air.

The *lactate of barytes* may be obtained in the same way as that of lime; but it then contains an excess of the base. When evaporated, it affords a gummy mass, soluble in alcohol. A portion remains undissolved, which is a sub-salt, is doughy, and has a browner colour. That which is dissolved in the alcohol affords by evaporation an almost colourless gummy mass, which hardens into a stiff but not a brittle varnish. It does not show the least tendency to crystallize. The salt, which is less soluble in alcohol, may be further purified from the animal matter adhering to it, by adding to it more barytes, and then becomes more soluble.

The *lactate of lime* is obtained in the manner above described. It affords a gummy mass, which is also divided by alcohol into two portions. The larger portion is soluble, and gives a shining varnish inclining to a light yellow colour, which, when slowly dried, cracks all over, and becomes opaque. This is pure lactate of lime. That which is insoluble in alcohol is a powder, with excess of the base; received on a filter, it becomes smooth in the air like gum, or like malate of lime. By boiling with more lime, and by the precipitation of the superfluous base upon exposure to the air, it becomes pure and soluble in alcohol.

Lactate of magnesia, evaporated to the consistence of a thin sirup, and left in a warm place, shoots into small granular crystals. When hastily evaporated to dryness, it affords a gummy mass. With regard to alcohol, its properties resemble those of the two preceding salts.

Ammoniaco-magnesian lactate is obtained by mixing the preceding salt with caustic ammonia, as long as any precipitation continues. By spontaneous evaporation this salt shoots into needle-shaped prisms, which are little coloured, and do not change in the air. Berzelius has once seen these crystals form in the alcoholic extract of milk boiled to dryness; but this is by no means a common occurrence.

The *lactate of silver* is procured by dissolving the carbonate in the lactic acid. The solution is of a light yellow, somewhat inclining to green, and has an unpleasant taste of verdigris. When evaporated in a flat vessel, it dries into a very transparent greenish yellow varnish, which has externally an unusual splendour like that of a looking-glass. If the evaporation is conducted in a deeper vessel, and with a stronger heat, a part of the salt is decomposed, and remains brown from the reduction of the silver. If this salt is dissolved in water, no inconsiderable portion of the silver is reduced and deposited, even when the salt has been transparent; and the concentrated solution has a fine greenish yellow colour, which by dilution becomes yellow. If we dissolve the oxide of silver in an impure acid, the salt becomes brown, and more silver is revived during the evaporation.

The *lactate of the protoxide of mercury* is obtained when the lactic acid is saturated with black oxidated mercury. It has a light yellow colour, which disappears by means of repeated solution and evaporation. The salt exhibits acid properties, deliquesces in the air, and is partially dissolved in alcohol, but is at the same time decomposed, and deposites carbonate of mercury, while the mixture acquires a slight smell of ether. The lactic acid dissolves also the red oxide of mercury, and gives with it a red gummy deliquescent salt. If it is left exposed to a warm and moist atmosphere, it deposites, after the expiration of some weeks, a light semi-crystalline powder, which he has not examined, but which probably must be acetate of mercury.

The *lactate of lead* may be obtained in several different degrees of saturation. If the lactic acid is digested with the carbonate of lead, it becomes browner than before, but cannot be fully saturated with the oxide; and we obtain an acid salt, which does not crystallize, but dries into a sirup-like brown mass, with a sweet austere taste. When a solution of lactic acid in alcohol is digested with finely powdered litharge, until the solution becomes sweet, and is then slowly evaporated to the consistence of honey, the neutral lactate of lead crystallizes in small grayish grains, which may be rinsed with alcohol, to wash off the viscid mass that adheres to them, and will then appear as a gray granular salt, which when dry is light and silvery.

This silver grained salt is not changed in the air; treated with sulphuretted hydrogen it affords pure lactic acid. If the lactic acid is digested with a greater portion of levigated litharge than is required for its saturation, the fluid acquires first a browner colour, and as the digestion is continued the colour becomes more and more pale, and the oxide swells into a bulky powder, of a colour somewhat lighter than before. If the fluid is evaporated, and water is then poured on the dry mass, a very small portion of it only is dissolved; the solution is not coloured, and when it is exposed to the air, a pellicle of carbonate of lead is separated from it. If the dried salt of lead be boiled with water, and the solution be filtered while hot, a great part of that which had been dissolved will be precipitated while it cools, in the form of a white, or light yellow powder, which is a sublactate of lead. This salt is of a light flame colour; when dried, it remains mealy, and soft to the touch, and it is decomposed by the weakest acids, while the acid salt is dissolved in water, exhibiting a sweet taste and a brown colour. When moistened with water, it undergoes this change from the operation of the carbonic acid diffused in the air. If this salt is warmed and then set on fire at one point, it burns like tinder, and leaves the lead in great measure reduced. A hundred parts of this salt, dissolved in nitric acid, and precipitated with carbonate of potash, gave exactly 100 parts of carbonate of lead; consequently its component parts, determined from those of the carbonate, must be 83 of the oxide of lead, and 17 of the lactic acid. At the same time we cannot wholly depend on this proportion, and it certainly makes the quantity of lead somewhat too great. The relation of the lactic acid to lead affords one of the best methods of recognizing it, and Berzelius always principally employed it in extracting this acid from animal fluids; it gives the clearest distinction between the lactic acid and the acetic.

The *lactate of iron* is of a red brown colour, does not crystallize, and is not soluble in alcohol. The *lactate of zinc* crystallizes. Both these metals are dissolved by the lactic acid, with an extrication of hydrogen gas. The *lactate of copper*, according to its different degrees of saturation, varies from blue to green and dark blue. It does not crystallize.

It is only necessary to compare the descriptions of these salts with what we know of the salts which are formed with the same bases by other acids, for example, the acetic, the malic, and others, in order to be completely convinced that the lactic acid must be a peculiar acid, perfectly distinct from all others. Its prime equivalent may be called 5.8.

The *nanceic acid* of Braconnot resembles the lactic in many respects.*

* ACID (LAMPIC). Sir H. Davy, during his admirable researches on the nature and properties of flame, announced the singular fact, that combustible bodies might be made to combine rapidly with oxygen, at temperatures below what were necessary to their *visible* inflammation. Among the phenomena resulting from these new combinations, he remarked the production of a peculiar acid and pungent vapour from the slow combustion of ether; and from its obvious qualities he was led to suspect, that it might be a product yet new to the chemical catalogue. Mr. Faraday, in the 3d volume of the Journal of Science and the Arts, has given some account of the properties of this new acid; but from the very small quantities in which he was able to collect it, was prevented from performing any decisive experiments upon it.

In the 6th volume of the same Journal, we have a pretty copious investigation of the properties and compounds of this new acid, by Mr. Daniell. From the slow combustion of ether during six weeks, by means of a coil of platina wire sitting on the cotton wick of the lamp, (See FLAME), he condensed with the head of an alembic, whose beak was inserted in a receiver, a pint and a half of the lampic acid liquor.

When first collected it is a colourless fluid of an intensely sour taste, and pungent odour. Its vapour, when heated, is extremely irritating and disagreeable, and when received into the lungs produces an oppression at the chest very much resembling the effect of chlorine. Its specific gravity varies according to the care with which it has been prepared, from less than 1.000 to 1.008. It may be purified by careful evaporation; and it is worthy of remark, that the vapour which rises from it is that of alcohol, with which it is slightly contaminated, and not of ether. Thus rectified, its specific gravity is 1.015. It reddens vegetable blues, and decomposes all the earthy and alkaline carbonates, forming neutral salts with their bases, which are more or less deliquescent. Lampate of soda is a very deliquescent salt, of a not unpleasant saline taste. It is decomposed by heat. It consists of 62.1 acid and 37.9 soda. Hence its prime equivalent comes out 6.47. Lampate of potash is not quite so deliquescent. Lampate of ammonia evaporates at a temperature below 212°. It is a brown salt. Lampate of barytes crystallizes in colourless transparent needles. Its composition is 39.5 acid and 60.5 base; and hence the prime is 6.365, barytes being reckoned 9.75, with Dr. Wollaston. Lampate of lime is deliquescent, and has a caustic bitter taste. Lampate of magnesia has a sweet, astringent taste, like sulphate of iron. All these salts burn with flame. Lampic acid reduces gold from the muriate instantly; and the lampates of potash and ammonia produce the same effect more slowly. A mixture of these two lampates, throws down metallic platinum from its solution. Nitrate of silver also gives a metallic precipitate; but what is singular, the oxide of silver is soluble in lampic acid, but at a boiling heat falls down in the metallic state. A hot solution of nitrated protoxide of mercury exhibits a very beautiful phenomenon, when mixed with the acid. A shower of mercurial globules falls down through the liquid. Red oxide forms with lampic acid a bulky white salt, of sparing solubility, from which, after a few days, metallic mercury separates. Lampate of copper affords by evaporation under an exhausted receiver, blue rhomboidal crystals. When the solution is boiled, metallic copper falls. Lampate of lead is a white, sweetish, and easily crystallized salt.

By analysis of the lampate of barytes in M. M. G. Lussac and Thenard's apparatus, (See VEGETABLE ANALYSIS), Mr. Daniell infers the composition of the acid to be 40.7 carbon, + 7.7 hydrogen, + 51.6 of oxygen and hydrogen, in their aqueous ratio = 100. These numbers correspond, he says, with what we may suppose to result from 1 atom of carbon, 1 of hydrogen, and 1 of water, or its elements. The excess of hydrogen explains, he imagines, the property which the acid possesses of reviving the metals, whence it may be usefully applied in the arts, to plate delicate works with gold and platinum.

The weight of its equivalent, and some of the properties of the salts, might lead to the opinion of the lampic acid of Mr.

Daniell being merely the acetic, combined with some etherous matter. This conjecture must be left for future verification.*

Acid (Lithic). This was discovered about the year 1776 by Scheele, in analyzing human calculi, of many of which it constitutes the greater part and of some, particularly that which resembles wood in appearance, it forms almost the whole. It is likewise present in human urine, and in that of the camel; and Dr. Pearson found it in those arthritic concretions commonly called chalkstones, which Mr. Tennant has since confirmed. It is often called *uric* acid.

The following are the results of Scheele's experiments on calculi, which were found to consist almost wholly of this acid:

1. Dilute sulphuric acid produced no effect on the calculus, but the concentrated dissolved it; and the solution distilled to dryness left a black coal, giving off sulphurous acid fumes. 2. The muriatic acid, either diluted or concentrated, had no effect on it even with ebullition. 3. Dilute nitric acid attacked it cold; and with the assistance of heat produced an effervescence and red vapour, carbonic acid was evolved, and the calculus was entirely dissolved. The solution was acid, even when saturated with the calculus, and gave a beautiful red colour to the skin in half an hour after it was applied; when evaporated, it became of a blood red, but the colour was destroyed by adding a drop of acid: it did not precipitate muriate of barytes, or metallic solutions, even with the addition of an alkali; alkalis rendered it more yellow, and, if superabundant, changed it by a strong digesting heat to a rose colour; and this mixture imparts a similar colour to the skin, and is capable of precipitating sulphate of iron black, sulphate of copper green, nitrate of silver gray, super-oxygenated muriate of mercury, and solutions of lead and zinc, white. Lime-water produced in the nitric solution a white precipitate, which dissolved in the nitric and muriatic acids without effervescence, and without destroying their acidity. Oxalic acid did not precipitate it. 4. Carbonate of potash did not dissolve it, either cold or hot, but a solution of perfectly pure potash dissolved it even cold. The solution was yellow; sweetish to the taste; precipitated by all the acids, even the carbonic; did not render lime-water turbid; decomposed and precipitated solution of iron brown, of copper gray, of silver black, of zinc, mercury, and lead, white; and exhaled a smell of ammonia. 5. About 200 parts of lime-water dissolved the calculus by digestion, and lost its acrid taste. The solution was partly precipitated by acids. 6. Pure water dissolved it entirely, but it was necessary to boil for some time 360 parts with one of the calculus in powder. This solution reddened tincture of litmus, did not render lime-water turbid, and on cooling deposited in small crystals almost the whole of what it had taken up. 7. Seventy-two grains distilled in a small glass retort over an open fire, and gradually brought to a red heat, produced water of ammonia mixed with a little animal oil, and a brown sublimate weighing 28 grains, and 12 grains of coal remained, which preserved its black colour on red hot iron in the open air. The brown sublimate was rendered white by a second sublimation; was destitute of smell, even when moistened by an alkali; was acid to the taste; dissolved in boiling water, and also in alcohol, but in less quantity; did not precipitate lime-water; and appeared to resemble succinic acid.

Fourcroy has found, that this acid is almost entirely soluble in 2000 times its weight of cold water, when the powder is repeatedly treated with it. From his experiments he infers, that it contains azote, with a considerable portion of carbon, and but little hydrogen, and little oxygen.

Of its combinations with the bases we know but little. The lithate of lime is more soluble than the acid itself; but on exposure to the air it is soon decomposed, the carbonic acid in the atmosphere combining with the lime, and precipitating both the lithic acid and new formed carbonate of lime separate from each other. The lithate of soda appears from the analysis of Mr. Tennant to constitute the chief part of the concretions formed in the joints of gouty persons. The lithate of potash is obtained by digesting calculi in caustic lixivium; and Fourcroy recommends the precipitation of the lithic acid from this solution by acetic acid, as a good process for obtaining the acid pure in small, white, shining, and almost pulverulent needles.

* Much additional information has been obtained within these few years on the nature and habitudes of the lithic acid. Dr. Henry wrote a medical thesis, and afterwards published a paper, on the subject, in the second volume of the new series of the Manchester Memoirs, both of which contain many important facts. He procured the acid in the manner above prescribed by Fourcroy. It has the form of white shining plates, which are denser than water. Has no taste nor smell. It dissolves in about 1400 parts of boiling water. It reddens the infusion of litmus. When dissolved in nitric acid, and evaporated to dryness, it leaves a pink sediment. The dry acid is not acted on nor dissolved by the alkaline carbonates, or sub-carbonates. It decomposes soap when assisted by heat; as it does also the alkaline sulphurets, and hydrosulphurets. No acid

acts on it, except those that occasion its decomposition. It dissolves in hot solutions of potash and soda, and likewise in ammonia, but less readily. The lithates may be formed, either by mutually saturating the two constituents, or we may dissolve the acid in an excess of base, and we may then precipitate by carbonate of ammonia. The lithates are all tasteless, and resemble in appearance lithic acid itself. They are not altered by exposure to the atmosphere. They are very sparingly soluble in water. They are decomposed by a red heat, which destroys the acid. The lithic acid is precipitated from these salts, by all the acids except the prussic and carbonic. They are decomposed by the nitrates, muriates, and acetates of barytes, strontites, lime, magnesia, and alumina. They are precipitated by all the metallic solutions except that of gold. When lithic acid is exposed to heat, the products are carburetted hydrogen, and carbonic acid, prussic acid, carbonate of ammonia, a sublimate, consisting of ammonia combined with a peculiar acid, which has the following properties:—

Its colour is yellow, and it has a cooling bitter taste. It dissolves readily in water, and in alkaline solutions, from which it is not precipitated by acids. It dissolves also sparingly in alcohol. It is volatile, and when sublimed a second time, becomes much whiter. The watery solution reddens vegetable blues, but a very small quantity of ammonia destroys this property. It does not cause effervescence with alkaline carbonates. By evaporation it yields permanent crystals, but ill defined, from adhering animal matter. These redden vegetable blues. Potash when added to these crystals, disengages ammonia. When dissolved in nitric acid, they do not leave a red stain, as happens with uric acid; nor does their solution in water decompose the earthy salts, as happens with alkaline lithates (or urates.) Neither has it any action on the salts of copper, iron, gold, platinum, tin, or mercury. With nitrates of silver, and mercury, and acetate of lead, it forms a white precipitate, soluble in an excess of nitric acid. Muriatic acid occasions no precipitate in the solution of these crystals in water. These properties show, that the acid of the sublimate is different from the uric, and from every other known acid. Dr. Austin found, that by repeated distillations, lithic acid was resolved into ammonia, nitrogen, and prussic acid. See Acid (Pyrolithic.)

When lithic acid is projected into a flask with chlorine, there is formed, in a little time, muriate of ammonia, oxalate of ammonia, carbonic acid, muriatic acid, and malic acid; the same results are obtained by passing chlorine through water, holding this acid in suspension.

M. Gay-Lussac mixed lithic acid with 20 times its weight of oxide of copper, put the mixture into a glass tube, and covered it with a quantity of copper filings. The copper filings being first heated to a dull red heat, was applied to the mixture. The gas which came over, was composed of 0.69 carbonic acid, and 0.31 nitrogen. He conceives, that the bulk of the carbonic acid would have been exactly double that of the nitrogen, had it not been for the formation of a little carbonate of ammonia. Hence, uric acid contains two prime equivalents of carbon, and one of nitrogen. This is the same proportion as exists in cyanogen. Probably, a prime equivalent of oxygen is present. Dr. Prout, in the eighth vol. of the Med. Chir. Trans. describes the result of an analysis of lithic acid, effected also by ignited oxide of copper, but so conducted as to determine the product of oxygen and hydrogen. Four grains of lithic acid yielded, water 1.05, carbonic acid 11.0 c. inches, nitrogen 5.5 do. Hence, it consisted of

Hydrogen	2.857	or 1 prime	= 0.125
Carbon	34.286	2	= 1.500
Oxygen	22.857	1	= 1.000
Nitrogen	40.000	1	= 1.750
	100.000		4.375

M. Berard has published an analysis of lithic acid since Dr. Prout, in which he also employed oxide of copper.

The following are the results:—

Carbon	33.61	which approach to	2 Carbon
Oxygen	18.89		1 Oxygen
Hydrogen	8.34		4 Hydrogen
Nitrogen	39.16		1 Nitrogen
	100.00		

Here we find the nitrogen and carbon nearly in the same quantity as by Dr. Prout, but there is much more hydrogen and less oxygen. By urate of barytes, we have the prime equivalent of uric acid equal to 15.67; and by urate of potash it appears to be 14.0. It is needless to try to accommodate an arrangement of prime equivalents to these discrepancies. The lowest number would require, on the Daltonian plan, an association of more than twenty atoms, the grouping of which is rather a sport of fancy, than an exercise of reason. For what benefit could accrue to chemical science, by stating, that if we consider the atom of lithic acid to be 16.75, then it would probably consist of

7 atoms	Carbon	= 5.25	31.4
3	Oxygen	= 3.00	17.90
12	Hydrogen	= 1.500	8.90
4	Nitrogen	= 7.00	41.80
26		16.75	100.00

* Acid (Malic.) The acid of apples; the same with that which is extracted from the fruit of the mountain ash. See Acid (Sorbic.*)

* Acid (Margaric.) When we immerse soap made of pork-grease and potash, in a large quantity of water, one part is dissolved, while another part is precipitated, in the form of several brilliant pellets. These are separated, dried, washed in a large quantity of water, and then dried on a filter. They are now dissolved in boiling alcohol, sp. gr. 0.820, from which, as it cools, the pearly substance falls down pure. On acting on this with dilute muriatic acid, a substance of a peculiar kind, which M. Chevreul, the discoverer, calls margarine, or margaric acid, is separated. It must be well washed with water dissolved in boiling alcohol, from which it is recovered in the same crystalline pearly form, when the solution cools.

Margaric acid is pearly white, and tasteless. Its smell is feeble, and a little similar to that of melted wax. Its specific gravity is inferior to water. It melts at 134° F. into a very limpid, colourless liquid, which crystallizes on cooling, into brilliant needles of the finest white. It is insoluble in water, but very soluble in alcohol, sp. gr. 0.800. Cold margaric acid has no action on the colour of litmus; but when heated so as to soften without melting, the blue was reddened. It combines with the salifiable bases, and forms neutral compounds. 100 parts of it unite to a quantity of base containing three parts of oxygen, supposing that 100 of potash contain 17 of oxygen. Two orders of margarates are formed, the margarates, and the supermargarates, the former being converted into the latter, by pouring a large quantity of water on them. Other fats besides that of the hog yield this substance.

	Acid.	*Base.*
Margarate of potash consists of	100	17.77
Supermargarate - - - -	100	8.88
Margarate of soda - - - -	100	12.72
Barytes - - - - - - - -	100	28.93
Strontites - - - - - - -	100	20.23
Lime - - - - - - - - -	100	11.06
		Potash
Supermargarate of Human fat	100	8.85
Sheep fat	100	8.68
Ox fat	100	8.78
Jaguar fat	100	8.60
Goose fat	100	8.77

If we compare the above numbers, we shall find 35 to be the prime equivalent of margaric acid.

That of man is obtained under three different forms. 1st, In very fine long needles, disposed in flat stars. 2d, In very fine and very short needles, forming waved figures, like those of the margaric acid of carcasses. 3d, In very large brilliant crystals disposed in stars, similar to the margaric acid of the hog. The margaric acids of man and the hog resemble each other; as do those of the ox and the sheep; and of the goose and the jaguar. The compounds with the bases, are real soaps. The solution of alcohol affords the transparent soap of this country.—*Annales de Chimie*, several volumes.*

* Acid (Meconic). This acid is a constituent of opium. It was discovered by M. Sertuerner, who procured it in the following way: After precipitating the *morphia*, from a solution of opium, by ammonia, he added to the residual fluid a solution of the muriate of barytes. A precipitate is in this way formed, which is supposed to be a quadruple compound, of barytes, morphia, extract, and the meconic acid. The extract is removed by alcohol, and the barytes by sulphuric acid; when the meconic acid is left, merely in combination with a portion of the morphia; and from this it is purified by successive solutions and evaporations. The acid, when sublimed, forms long colourless needles; it has a strong affinity for the oxide of iron, so as to take it from the muriatic solution, and form with it a cherry-red precipitate It forms a crystallizable salt with lime, which is not decomposed by sulphuric acid; and what is curious, it seems to possess no particular power over the human body, when received into the stomach. The essential salt of opium, obtained in M. Derosne's original experiments, was probably the meconiate of morphia.

Mr. Robiquet has made a useful modification of the process for extracting meconic acid. He treats the opium with magnesia, to separate the morphia, while meconiate of magnesia is also formed. The magnesia is removed by adding muriate of barytes, and the barytes is afterwards separated by dilute sulphuric acid. A larger proportion of meconic acid is thus obtained.

Mr. Robiquet denies that meconic acid precipitates iron from the muriate; but, according to M. Vogel, its power of reddening solutions of iron is so great, as to render it a more delicate test of this metal, than even the prussiate of potash.

To obtain pure meconic acid from the meconiate of barytes, M. Choulant triturated it in a mortar, with its own weight of glassy boracic acid. This mixture being put into a small glass flask, which was surrounded with sand in a sand pot, in the usual manner, and the red heat being gradually raised, the *meconic* acid sublimed, in the state of fine white scales or plates. It has a strong sour taste, which leaves behind it an impression of bitterness. It dissolves readily in water, alcohol, and ether. It reddens the greater number of vegetable blues, and changes the solutions of iron to a cherry-red colour. When these solutions are heated, the iron is precipitated in the state of protoxide.

The *meconiates* examined by Choulant, are the following:—

1st, Meconiate of potash. It crystallizes in four sided tables, is soluble in twice its weight of water, and is composed of

Meconic acid	27	2.7
Potash	60	6.0
Water	13	
	100	

It is destroyed by heat.

2d, Meconiate of soda. It crystallizes in soft prisms, is soluble in five times its weight of water, and seems to effloresce. It is destroyed by heat. It consists of

Acid	32	3.2
Soda	40	4.0
Water	28	
	100	

3d, Meconiate of ammonia. It crystallizes in star-form needles, which, when sublimed, lose their water of crystallization, and assume the shape of scales. The crystals are soluble in 1½ their weight of water, and are composed of

Acid	40	2.03
Ammonia	42	2.13
Water	18	
	100	

If two parts of sal ammoniac be triturated with 3 parts of meconiate of barytes, and heat be applied to the mixture, meconiate of ammonia sublimes, and muriate of barytes remains.

4th, Meconiate of lime. It crystallizes in prisms, and is soluble in eight times its weight of water. It consists of

Acid	34	2.882
Lime	42	3.560
Water	24	
	100	

As the potash and lime compounds give nearly the same acid ratio, we may take their mean of it, as the true prime = 2.8.*

* Acid (Melassic). The acid present in melasses, which has been thought a peculiar acid by some, by others, the acetic.*

Acid (Mellitic). M. Klaproth discovered in the mellite, or honey-stone, what he conceives to be a peculiar acid of the vegetable kind, combined with alumina. This acid is easily obtained by reducing the stone to powder, and boiling it in about 70 times its weight of water; when the acid will dissolve, and may be separated from the alumina by filtration. By evaporating the solution, it may be obtained in the form of crystals. The following are its characters:—

It crystallizes in fine needles or globules by the union of these, or small prisms. Its taste is at first a sweetish sour, which leaves a bitterness behind. On a plate of hot metal it is readily decomposed, and dissipated in copious gray fumes, which affect not the smell; leaving behind a small quantity of ashes, that do not change either red or blue tincture of litmus. Neutralized by potash it crystallizes in groups of long prisms: by soda, in cubes, or triangular laminæ, sometimes in groups, sometimes single; and by ammonia, in beautiful prisms with six planes, which soon lose their transparency, and acquire a silvery white hue. If the mellitic acid be dissolved in lime-water, and a solution of calcined strontian or barytes be dropped into it, a white precipitate is thrown down, which is redissolved on adding muriatic acid. With a solution of acetate of barytes, it produces likewise a white precipitate, which nitric acid redissolves. With solution of muriate of barytes, it produces no precipitate, or even cloud; but after standing some time, fine transparent needly crystals are deposited. The mellitic acid produces no change in a solution of nitrate of silver. From a solution of nitrate of mercury, either hot or cold, it throws down a copious white precipitate, which an addition of nitric acid immediately redissolves. With nitrate of iron it gives an abundant precipitate of a dun yellow colour, which may be redissolved by muriatic acid. With a solution of acetate of lead, it produces an abundant precipitate, immediately redissolved on adding nitric acid. With acetate of copper, it produces a grayish-green precipitate; but it does not affect a solution of muriate of copper. Lime-water precipitated by it, is immediately redissolved on adding nitric acid.

M. Klaproth was never able to convert this acid into the oxalic by means of nitric acid, which only changed its brownish colour to a pale yellow.

* The *mellite*, or native mellate of alumina, consists, according to Klaproth, of 46 acid + 16 alumina + 38 water = 100; from which, calling the prime of alumina 3.2, that of mellitic acid appears to be 9.2.*

* Acid (Menispermic). The seeds of *menispermum cocculus* being macerated for 24 hours in 5 times their weight of water, first cold, and then boiling hot, yield an infusion, from which solution of subacetate of lead throws down a menispermate of lead. This is to be washed and drained, diffused through water, and decomposed by a current of sulphuretted hydrogen gas. The liquid thus freed from lead, is to be deprived of sulphuretted hydrogen by heat, and then forms solution of minis-

lent of chlorine 4.43, which comes near to Berzelius's latest result; while his first number makes it 4.48, (See Chlorine). As the attraction of muriatic acid gas for hygrometric water is very strong, it is very probable that 38.4 grs. may be the more exact weight of 100 cubic inches, regarding the same bulk of air as = 30.5. If an inflamed taper be immersed in it, it is instantly extinguished. It is destructive of animal life; but the irritation produced by it on the epiglottis scarcely permits its descent into the lungs. It is merely changed in bulk by alterations of temperature; it experiences no change of state. When potassium, tin, or zinc, is heated in contact with this gas over mercury, one-half of the volume disappears, and the remainder is pure hydrogen. On examining the solid residue, it is found to be a metallic chloride. Hence muriatic acid gas consists of chlorine and hydrogen, united in equal volumes. This view of its nature was originally given by Scheele, though obscured by terms derived from the vague and visionary hypothesis of phlogiston. The French school afterwards introduced the belief that muriatic acid gas was a compound of an unknown radical and water; and that chlorine consisted of this radical and oxygen. Sir H. Davy has the distinguished glory of refuting the French hypothesis, and of proving by decisive experiments, that in the present state of our knowledge, chlorine must be regarded as a simple substance; and muriatic acid gas as a compound of it with hydrogen.

This gaseous acid unites rapidly, and in large quantity, with water. The following table of its aqueous combinations, was constructed after experiments made by Mr. E. Davy, in the laboratory of the Royal Institution, under the inspection of Sir H. Davy.

At temperature 45°, barometer 30.

100 parts of solution of muriatic gas, in water, of sp. gravity		Of muriatic acid gas, parts.
1.21	contain	42.43
1.20		40.80
1.19		38.38
1.17		34.34
1.16		32.32
1.15		30.30
1.14		28.28
1.13		26.26
1 12		24.24
1.11		22.30
1.10		20.20
1.09		18.18
1.08		16.16
1.07		14.14
1.06		12.12
1.05		10.10
1.04		8.08
1.03		6.06
1.02	contain	4.04
1.01		2.02

At the temperature of 40° Fahrenheit, water absorbs about 480 times its bulk of gas, and forms solution of muriatic acid gas in water, the specific gravity of which is 1.2109.—*Sir H. Davy's Elements.*

In the Annals of Philosophy for October and November 1817, there are two papers on the constitution of liquid muriatic acid with tables, by Dr. Ure, which coincide nearly with the preceding results. They were founded on a great number of experiments carefully performed, which are detailed in the October number. In mixing strong liquid acid with water, he found that some heat is evolved, and a small condensation of volume is experienced, contrary to the observation of Mr. Kirwan. Hence this acid forms no longer an exception, as that eminent chemist taught, to the general law of condensation of volume, which liquid acids obey in their progressive dilutions. Hitherto indeed many chemists have, without due consideration, assumed the half-sum or *arithmetical* mean of two specific gravities, to be the truly *computed* mean; and on comparing the number thus obtained with that derived from experiment, they have inferred the change of volume, occasioned by chemical combination. The errors into which this false mode of computation leads are excessively great, when the two bodies differ considerably in their specific gravities. A view of these erroneous results was given in Dr. Ure's third table of sulphuric acid, published in the 7th number of the Journal of Sciences and the Arts, and reprinted in this Dictionary, article Specific Gravity. When, however, the two specific gravities do not differ much, the errors become less remarkable. It is a singular fact, that the *arithmetical* mean, which is always *greater* than the rightly *computed* mean specific gravity, gives in the case of liquid muriatic acid, an error in excess, very nearly equal to the actual increase of density. The curious coincidence thus accidentally produced, between accurate experiments and a false mode of calculation is very instructive, and ought to lead chemists to verify every anomalous phenomenon, by independent modes of research. Had Mr. Kirwan, for example, put into a nicely graduated tube 50 measures of strong muriatic acid, and poured gently over it 50 measures of water, he would have found after agitation, and cooling the mixture to its former temperature, that there was a decided diminution of volume, as Dr. Ure experimentally ascertained.*

TABLE of real Muriatic Acid, &c. in 100 of the Liquid Acid, by Dr. Ure.

Sp. Gr.	*Dry Acid.*	*Acid Gas.*	*Chlorine.*	*Sp. Gr.*	*Dry Acid.*	*Acid Gas.*	*Chlorine.*	*Sp. Gr.*	*Dry Acid.*	*Acid Gas.*	*Chlorine.*
1.1920	28.3	37.60	36.50	1.1272	18.68	24.82	24.09	1.0610	9.05	12 03	11.68
1.1900	28.02	37.22	36.13	1.1253	18.39	24.44	23.72	1.0590	8.77	11.65	11.31
1.1881	27.73	36.85	35.77	1.1233	18.11	24.06	23.36	1.0571	8.49	11.28	10.95
1.1863	27 45	36.47	35.40	1.1214	17.83	23.69	22.99	1.0552	8.21	10.90	10.58
1.1845	27.17	36.10	35.04	1.1194	17.55	23.31	22.63	1.0533	7.92	10.53	10.22
1.1827	26.88	35.72	34.67	1.1173	17.26	22.93	22.26	1.0514	7.64	10.15	9.85
1.1808	26.60	35.34	34.31	1.1155	16.98	22.56	21.90	1.0495	7.36	9.77	9.49
1.1790	26.32	34.97	33.94	1.1134	16.70	22.18	21.53	1.0477	7.07	9.40	9.12
1.1772	26.04	34.59	33.58	1.1115	16.41	21.81	21.17	1.0457	6.79	9.02	8.76
1.1753	25.75	34.22	33.21	1.1097	16.13	21.43	20.80	1.0438	6.51	8.65	8.39
1.1735	25.47	33.84	32.85	1.1077	15.85	21.05	20.44	1.0418	6.23	8.27	8.03
1.1715	25.19	33.46	32.48	1.1058	15.56	20.68	19.07	1.0399	5.94	7.89	7.66
1.1698	24.90	33.09	32.12	1.1037	15.28	20.30	19.71	1.0380	5.66	7.52	7.30
1.1679	24.62	32.71	31.75	1.1018	15.00	19.93	19.34	1.0361	5.38	7.14	6.93
1.1661	24.34	33.34	31.39	1.0999	14.72	19.55	18.98	1.0342	5.09	6.77	6.57
1.1642	24.05	31.96	31.02	1.0980	14.43	19.17	18.61	1.0324	4.81	6.39	6.20
1.1624	23.77	31.58	30.66	1.0960	14.15	18.80	18.25	1.0304	4.53	6.02	5.84
1.1605	23.49	31.21	30.29	1.0941	13.87	18.42	17.88	1.0285	4.24	5.64	5.47
1.1587	23.20	30.83	29.93	1.0922	13.58	18.04	17.52	1.0266	3.96	5.26	5.11
1.1568	22.92	30.46	29.56	1.0902	13.30	17.67	17.15	1.0247	3.68	4.89	4.74
1.1550	22.64	30.08	29.20	1.0883	13.02	17.29	16.79	1.0228	3.39	4.51	4.38
1.1531	22.36	29.70	28 83	1.0863	12.73	16.92	16.42	1.0209	3.11	4.14	4.01
1.1510	22.07	29.33	28.47	1.0844	12.45	16.54	16.06	1.0190	2.83	3.76	3.65
1.1491	21.79	29.95	28.10	1.0823	12.17	16.17	15.69	1.0171	2.55	3.38	3.28
1.1471	21.51	28.57	27.74	1.0805	11.88	15.79	15.33	1.0152	2.26	3.01	2.92
1.1452	21.22	28.20	27.37	1.0785	11.60	15.42	14.96	1.0133	1.98	2.63	2.55
1.1431	20.94	27.82	27.01	1.0765	11.32	15.04	14.60	1.0114	1.70	2.26	2.19
1.1410	20.66	27.45	26.64	1.0746	11.04	14.66	14.23	1.0095	1.41	1.88	1.82
1.1391	20.37	27.07	26.28	1.0727	10.75	14.29	13.87	1.0076	1.13	1.50	1.46
1.1371	20.09	26.69	25.91	1.0707	10.47	13.91	13.50	1.0056	0.85	1.13	1.09
1.1351	19.81	26.32	25.55	1.0688	10.19	13.54	13.14	1.0037	0.56	0.752	0.73
1.1332	19.53	29.94	25.18	1.0669	9.90	13.16	12.77	1.0019	0.28	0.376	0.365
1.1312	19.24	25.57	24.82	1.0649	9.62	12.78	12.41	1.000	0.00	0.000	0.000
1.1293	18.96	25.19	24.45	1.0629	9.34	12.41	12.04				

The fundamental density of the acid of the preceding table is 1.1920, which is as strong as it is comfortable to make or to use in chemical researches. To find the quantity of real acid in that possessed of greater density, we have only to dilute it with a known proportion of water, till it come within the range of the table. The short memoir in the Annals for November, contains the logarithmic series corresponding to the range of densities and acid strengths; but for all ordinary purposes the following simple rule will serve: Multiply the decimal part of the number denoting the specific gravity by 147, the product will be very nearly the per-centage of dry acid, or by 197 when we wish to know the per-centage of the acid gas.

Examples. 1. The specific gravity is 1.141; required the proportion of dry acid in 100 parts.

0.141 × 147 = 20.72. By the table it is 20.66.

2. The specific gravity is 1.096; the quantity of acid gas is sought.

0.096 × 197 = 18.9. By the table it is 18.8.

According to the new doctrine of Sir H. Davy there is no such substance as the dry acid; and therefore in a theoretical point of view, the column containing it might have been expunged. But for practical purposes it is very useful, for it shows directly the increase of weight which any alkaline or earthy base will acquire, by combining with the liquid acid. Thus, if we unite 100 grs. of liquid acid sp. gravity 1.1134 with quicklime, we see that the base will, on evaporation to dryness, be heavier by 16.7 grains. We would require a little calculation to determine this amount from the other columns. We have seen it stated that water, in absorbing 480 times its bulk of the acid gas, becomes of specific gravity 1.2109. If we compute from these *data* the increase of its *bulk*, we shall find it equal to 1.42, or nearly one and a half the volume of the water. 481 parts occupy only 1.42 in bulk, a condensation of about 340 into one. The consequence of this approximation of the particles, is the evolution of their latent heat; and accordingly the heat produced in the condensation of the gas is so great that it melts ice almost as rapidly as the steam of boiling water does. Hence also in passing the gas from the beak of a retort into a Woulfe's apparatus containing water to be impregnated, it is necessary to surround the bottles with cold water or ice, if we wish a considerable condensation.

Dr. Thomson, in the second volume of his System of Chemistry, 5th edition, has committed some curious mistakes in treating of the aqueous combination of muriatic acid gas. He says, "A cubic inch of water at the temperature of 60°, barometer 29.4, absorbs 515 cubic inches of muriatic acid gas, which is equivalent to 308 grains nearly. Hence water thus impregnated contains 0.548, or more than half of its weight of muriatic acid, in the same state of purity, as when gaseous. I caused a current of gas to pass through water, till it refused to absorb any more. The specific gravity of the acid thus obtained was 1.203. If we suppose that the water in this experiment absorbed as much gas as in the last, it will follow from it that 6 parts of water, being saturated with this gas, expanded so as to occupy very nearly the bulk of 11 parts; but in all my trials the expansion was only to 9 parts. This would indicate a specific gravity of 1.477; yet upon actually trying water thus saturated, its specific gravity was only 1.203. Is this difference owing to the gas that escapes during the taking of the specific gravity?" page 232.

We are here presented with a puzzle for the chemical student; and an instructive example, when one takes the trouble of unravelling the bank, of a contest between experimental results and false computation. Granting all the experimental statements to be exact, none of the consequences follow. For, in the first place, 515 cubic inches of muriatic acid gas do not weigh 308 grains nearly, but only 201 grains; and hence, secondly, his liquid acid could contain at utmost only 0.443 of its weight of gas, instead of 0.548; and, in the third place, the calculated enlargement of bulk is 1.5, or from 6 to 9, and not to 11; so that the *quere* with which he concludes is superseded. But another *quere* may here be started, about the experimental results themselves. Dr. Thomson says, that a cubic inch of water absorbs 515 cubic inches of gas, and acquires the specific gravity by experiment of 1.203. Sir H. Davy states, that a cubic inch of water absorbs about 480 cubic inches of gas, and forms a liquid of specific gravity 1.2109. Now it is remarkable that Dr. Thomson's additional condensation of 35 inches of gas gives a *less* specific gravity than we have in the *stronger* acid of Sir H. Davy.

But farther, the table constructed by Sir H. and E. Davy presents for its fundamental density the number 1.20 of Dr. Thomson. Now this particular acid of 1.20 was carefully analyzed by nitrate of silver, and is stated by Sir H. to contain in 100 grains 40.8 grains of condensed gas. Of course we have a remainder of 59.2 grains of water. 40.8 gr. of gas have a volume at the ordinary pressure and temperature of 104 cubic inches, reckoning the weight of 100 cubic inches to be 39.162 gr. with Dr. Thomson. And as 59.2 gr. of water have absorbed 104 cubic inches, we have the following proportion, 59.2 : 104 : : 252.5 : 443. Thus a cubic inch has condensed only 443 cubic inches, instead of 515. as by Dr. Thomson. And whatever error may be supposed to be in their table, it is but minute, and undoubtedly does not consist in *underrating* the quantity of condensed gas.

By uniting the base of this gas with silver, and also with potassium, Berzelius has lately determined the prime equivalent of muriatic acid to be 3.4261, whence chlorine comes out 4.4261, and muriatic gas 4.4261 + 0.125 (the prime of hydrogen) = 4.5511. But if we take 1.278 as the specific gravity of this acid gas, then the specific gravity of chlorine will be twice that number, *minus* the specific gravity of hydrogen, or (1.278 × 2) —0.0694 = 2.4866; and as chlorine and hydrogen unite volume to volume, then the relation of the prime of chlorine will be to that of hydrogen $= \frac{2.4866}{0.0694} = 35.83$. If we divide this by 8, we shall have 4.48, to represent the prime equivalent of chlorine, and 4.48 + 0.125 = 4.605 for that of muriatic acid gas.

But if we call the specific gravity of dry muriatic acid gas 1.2590, as Sir H. Davy says it should be by calculation, then the sp. gravity of chlorine becomes 2.4486, and its prime 4.42, a number agreeing nearly with the latest researches of Berzelius.

Muriatic acid, from its composition, has been termed by M. Gay-Lussac the hydrochloric acid; a name objected to, on good grounds, by Sir H. Davy. It was prepared by the older chemists in a very rude manner, and was called by them spirit of salt.*

In the ancient method, common salt was previously decrepitated, then ground with dried clay, and kneaded or wrought with water to a moderately stiff consistence, after which it was divided into balls of the size of a pigeon's egg: these balls, being previously well dried, were put into a retort, so as to fill the vessel two-thirds full; distillation being then proceeded upon, the muriatic acid came over when the heat was raised to ignition. In this process eight or ten parts of clay to one of salt are to be used. The retort must be of stone-ware well coated, and the furnace must be of that kind called reverberatory.

It was formerly thought, that the salt was merely divided in this operation by the clay, and on this account more readily gave out its acid; but there can be little doubt, that the effect is produced by the siliceous earth, which abounds in large proportions in all natural clays, and detains the alkali of the salt by combining with it.

* Sir H. Davy first gave the just explanation of this decomposition. Common salt is a compound of sodium and chlorine. The sodium may be conceived to combine with the oxygen of the water in the earth, and with the earth itself, to form a vitreous compound; and the chlorine to unite with the hydrogen of the water, forming muriatic acid gas. "It is also easy," adds he, "according to these new ideas, to explain the decomposition of salt by moistened litharge, the theory of which has so much perplexed the most acute chemists. It may be conceived to be an instance of compound affinity; the chlorine is attracted by the lead, and the sodium combines with the oxygen of the litharge, and with water, to form hydrate of soda, which gradually attracts carbonic acid from the air. When common salt is decomposed by oil of vitriol, it was usual to explain the phenomenon by saying, that the acid by its superior affinity, aided by heat, expelled the gas, and united to the soda. But as neither muriatic acid nor soda exists in common salt, we must now modify the explanation, by saying that the water of the oil of vitriol is first decomposed, its oxygen unites to the sodium to form soda, which is seized on by the sulphuric acid, while the chlorine combines with the hydrogen of the water, and exhales in the form of muriatic acid gas."

As 100 parts of dry sea salt, are capable of yielding 62 parts by weight of muriatic acid gas, these ought to afford by economical management nearly 221 parts of liquid acid, specific gravity 1.142, as prescribed by the London College, or 200 parts of acid sp. gr. 1.160, as directed by the Edinburgh and Dublin Pharmacopeias.

The fluid ounce of the London College being $\frac{1}{16}$ of a wine pint, is equal in weight to 1.265817 lbs. Troy, divided by 16, which gives 453.7 grains Troy. This weight multiplied by 1.142 = the specific gravity of their standard acid, gives the product 520.4; which being multiplied by 0.2763, the muriatic gas in 1.00 by Dr. Ure's table, we have 143.8 or 144 for the acid gas in the liquid ounce, of the above density. We find this quantity equivalent to 200 gr. of carbonate of lime. Had the fundamental number 28.3 of Dr. Ure's table been made 28.6, as one of his experiments related in the Annals of Philosophy indicates, then a liquid ounce of the above acid would have dissolved upwards of 202 grains of pure calcareous carbonate. But when the results fluctuate between 28.3 and 28.6, they become exceedingly difficult to decide upon. As the difference is altogether unimportant in practice, he does not feel himself justified in making any alteration in his table. The limit of its error is certainly a fraction of one per cent. Were 29.0 the leading number, then a liquid oz. of acid of 1.142, would dissolve 205 grains of calc spar. It is obvious that the series of specific gravities given in the above table, is altogether independent of this question. If 28.6 should be preferred by any person, let him multiply this number by 0.9, 0.8, 0.7, 0.6, &c. and he will have a series of numbers representing the quantities of dry acids corresponding to the specific gravities 1.190, 1.1735, 1.1550, 1.1351, &c. for these densities are opposite to 90, 80, 70, 60, &c. per cent of the strong acid. When this acid is contaminated with sulphuric acid, it affords precipitates with muriates of barytes and strontites.*

We have described the ancient method of extracting the gas from salt, which is now laid aside.

The English manufacturers use iron stills for this distillation, with earthen heads: the philosophical chemist, in making the *acid of commerce*, will doubtless prefer glass. Five parts, by weight, of strong sulphuric acid are to be added to six of decrepitated sea salt, in a retort, the upper part of which is furnished with a tube or neck, through which the acid is to be poured upon the salt. The aperture of this tube must be closed with a ground stopper immediately after the pouring. The sulphuric acid immediately combines with the alkali, and expels the muriatic acid in the form of a peculiar air, which is rapidly absorbed by water. As this combination and disengagement take place without the application of heat, and the aërial fluid escapes very rapidly, it is necessary to arrange and lute the vessels together before the sulphuric acid is added, and not to make any fire in the furnace until the disengagement begins to slacken; at which time it must be very gradually raised. Before the modern improvements in chemistry were made, a great part of the acid escaped for want of water to combine with; but by the use of Woulfe's apparatus, (See LABORATORY,) the acid air is made to pass through water, in which it is nearly condensed, and forms muriatic acid of double the weight of the water, though the bulk of this fluid is increased one-half only. The acid condensed in the first receiver, which contains no water, is of a yellow colour, arising from the impurities of the salt.

The marine acid in commerce has a straw colour: but this is owing to accidental impurity; for it does not obtain in the acid produced by the impregnation of water with the pure aëriform acid.

The muriatic acid is one of those longest known, and some of its compounds are among those salts with which we are most familiar.

* The muriates, when in a state of dryness, are actually chlorides, consisting of chlorine and the metal; but since moisture makes them instantly pass to the state of muriates, we shall describe them under this article. The sulphates and nitrates, when destitute of water, may in like manner be regarded as containing neither acid nor alkali, and might therefore be transported to some new department of classification, to be styled sulphides and nitrides, as we shall see in treating of salts.*

The muriate of barytes crystallizes in tables bevelled at the edges, or in octaëdral pyramids applied base to base. It is soluble in five parts of water at 60°, in still less at a boiling heat, and also in alcohol. It is not altered in the air, and but partly decomposable by heat. The sulphuric acid separates its base; and the alkaline carbonates and sulphates decompose it by double affinity. It is best prepared by dissolving the carbonate in dilute muriatic acid; and if contaminated with iron or lead, which occasionally happens, these may be separated by the addition of a small quantity of liquid ammonia, or by boiling and stirring the solution with a little barytes. Mr. Goettling recommends to prepare it from the sulphate of barytes: eight parts of which in fine powder are to be mixed with two of muriate of soda, and one of charcoal powder. This is to be pressed hard into a Hessian crucible, and exposed for an hour and a half to a red heat in a wind furnace. The cold mass, being powdered, is to be boiled a minute or two in sixteen parts of water, and then filtered. To this liquor muriatic acid is to be added by little and little, till sulphuretted hydrogen ceases to be evolved; it is then to be filtered, a little hot water to be poured on the residuum, the liquor evaporated to a pellicle, filtered again, and then set to crystallize. As the muriate of soda is much more soluble than the muriate of barytes, and does not separate by cooling, the muriate of barytes will crystallize into a perfectly white salt, and leave the muriate of soda in the mother water, which may be evaporated repeatedly till no more muriate of barytes is obtained. This salt was first employed in medicine by Dr. Crawford, chiefly in scrofulous complaints and cancer, beginning with doses of a few drops of the saturated solution twice a-day, and increasing it gradually, as far as forty or fifty drops in some instances. In large doses it excites nausea, and has deleterious effects. Fourcroy says it has been found very successful in scrofula in France. It has likewise been recommended as a vermifuge; and it has been given with much apparent advantage, even to very young children, where the usual symptoms of worms occurred, though none were ascertained to be present. As a test of sulphuric acid it is of great use.

The muriate of potash, formerly known by the names of *febrifuge salt of Sylvius, digestive salt,* and *regenerated sea salt,* crystallizes in regular cubes, or in rectangular parallelopipedons; decrepitating on the fire, without losing much of their acid, and acquiring a little moisture from damp air, and giving it out again in dry. Their taste is saline and bitter. They are soluble in thrice their weight of cold water, and in but little less of boiling water, so as to require spontaneous evaporation for crystallizing. Fourcroy recommends, to cover the vessel with gauze, and suspend hairs in it, for the purpose of obtaining regular crystals.

It is sometimes prepared in decomposing sea salt by common potash for the purpose of obtaining soda; and may be formed by the direct combination of its constituent parts.

It is decomposable by the sulphuric and nitric acids. Barytes decomposes it, though not completely. And both silex and alumina decomposed it partially in the dry way. It decomposes the earthy nitrates, so that it might be used in saltpetre manufactories to decompose the nitrate of lime.

Muriate of soda, or *common salt*, is of considerable use in the arts, as well as a necessary ingredient in our food. It crystallizes in cubes, which are sometimes grouped together in various ways, and not unfrequently form hollow quadrangular pyramids. In the fire it decrepitates, melts, and is at length volatilized. When pure it is not deliquescent. One part is soluble in 2½ of cold water, and in little less of hot, so that it cannot be crystallized but by evaporation. According to M. Chenevix, it is soluble in alcohol also, particularly when it is mixed with the chlorate.

Common salt is found in large masses, or in rocks under the earth, in England and elsewhere. In the solid form it is called *sal gem* or *rock salt*. If it be pure and transparent, it may be immediately used in the state in which it is found; but if it contain any impure earthy particles, it should be previously freed from them. In some countries it is found in incredible quantities, and dug up like metals from the bowels of the earth. In this manner has this salt been dug out of the celebrated salt mines near Bochnia and Wieliczka, in Poland, ever since the middle of the 13th century, consequently above these 500 years, in such amazing quantities, that sometimes there have been 20,000 tons ready for sale. In these mines, which are said to reach to the depth of several hundred fathoms, 500 men are constantly employed. The pure and transparent salt needs no other preparation than to be beaten to small pieces, or ground in a mill. But that which is more impure must be elutriated, purified, and boiled. That which is quite impure, and full of small stones, is sold under the name of rock salt, and is applied to ordinary uses; it may likewise be used for strengthening weak and poor brine-springs.

Though the salt mines of Wieliczka, near Cracow in Poland, have long astonished the philosopher and traveller, yet it deserves to be remarked, that the quantity of rock salt obtained from the mines of Northwich is greatly superior to that obtained at Cracow. The bishop of Llandaff affirms, that a single pit, into which he descended, yielded at a medium 4000 tons of salt in a year, which alone is about two-thirds of that raised in the Polish mines. This rock salt is never used on our tables in its crude state, as the Polish rock salt is; and though the pure transparent salt might be used with our food, without any danger, yet it is prohibited under a penalty of 40s. for every pound of rock salt so applied. It is partly purified in water, and a great part of it is sent to Liverpool and other places, where it is used either for strengthening brine-springs or sea water.

Beside the salt mines here mentioned, where the common salt is found in a concrete state, under the name of rock salt, there is at Cordova, in the province of Catalonia in Spain, a remarkable solid mountain of rock salt; this mountain is between four and five hundred feet in height, and a league in circuit; its depth below the surface of the earth is not known. This mountain contains the rock salt without the least admixture of any other matter.

The waters of the ocean every where abound with common salt, though in different proportions. The water of the Baltic sea is said to contain one sixty-fourth of its weight of salt; that of the sea between England and Flanders contains one thirty-second part; that on the coast of Spain one sixteenth part; and between the tropics it is said, erroneously, to contain from an eleventh to an eighth part.

The water of the sea contains, besides the common salt, a considerable proportion of muriate of magnesia, and some sulphate of lime, of soda, and potash. The former is the chief ingredient of the remaining liquid which is left after the extraction of the common salt, and is called the mother water. Sea water, if taken up near the surface, contains also the putrid remains of animal substances, which render it nauseous, and in a long continued calm cause the sea to stink.

The whole art of extracting salt from waters which contain it, consists in evaporating the water in the cheapest and most convenient manner. In England, a brine composed of sea water, with the addition of rock salt, is evaporated in large shallow iron boilers; and the crystals of salt are taken out in baskets. In Russia, and probably in other northern countries, the sea water is exposed to freeze; and the ice, which is almost entirely fresh, being taken out, the remaining brine is much stronger, and is evaporated by boiling. In the southern parts of Europe the salt-makers take advantage of spontaneous evaporation. A flat piece of ground near the sea is chosen, and banked round, to prevent its being overflowed at high water. The space within the banks is divided by low walls into several compartments, which successively communicate with each other. At flood tide, the first of these is filled with sea water; which, by remaining a certain time, deposites its impurities, and loses part of its aqueous fluid. The residue is then suffered to run into the next compartment; and the former is again filled as before. From the second compartment, after a due time, the water is transferred into a third, which is lined with clay well rammed and levelled. At this period the evaporation is usually brought to that degree, that a crust of salt is formed on the surface of the water, which the workmen break, and it immediately falls to the bottom. They continue to do this, until the quantity is sufficient to be raked out, and dried in heaps. This is called *bay salt*.

In some parts of France, and also on the coast of China, they wash the dried sands of the sea with a small proportion of water, and evaporate this brine in leaden boilers.

There is no difference between this salt and the lake salt extracted from different lakes, excepting such as may be occasioned by the casual intervention of some substances. In this respect the Jeltonic salt water lake, in the Russian dominions, near Saratow and Dmitrewsk, deserves our attention. In the year 1748, when the Russians first fetched salt thence, the lake was almost solid with salt; and that to such a degree, that they drove their heavy wagons over it, as over a frozen river, and broke up the salt.† But since the year 1757 the water has increased so much, that at this time it is nothing more than a lake very strongly impregnated with salt. The Jeltonic lake salt contains at the same time alum and sulphate of magnesia.

At several places in Germany, and at Montmarot in France, the waters of salt springs are pumped up to a large reservoir at the top of a building or shed; from which it drops or trickles through small apertures upon boards covered with brushwood. The large surface of the water thus exposed to the air causes a very considerable evaporation; and the brine is afterward conveyed to the boilers for the perfect separation of the salt.

To free common salt from those mixtures that render it deliquescent, and less fit for the purposes to which it is applied, it may be put into a conical vessel with a small aperture at the point, and a saturated solution of the muriate of soda boiling hot be poured on it. This solution will dissolve and carry off any other salt mixed with the muriate of soda, and leave it quite pure, by repeating the process three or four times.

From this salt, as already observed, the muriatic acid is extracted; and of late years to obtain its base separate, in the most economical mode, for the purposes of the arts, has been an object of research. The process of Scheele, which consists in mixing the muriate of soda with red oxide of lead, making this into a soft paste with water, and allowing it to stand thus for some time, moistening it with water as it gets dry, and then separating the soda from the muriate of lead by lixiviation, has been resorted to in this country. Mr. Turner some years ago had a patent for it; converting the muriate of lead into a a pigment, which was termed *mineral* or *patent yellow*, by heating it to fusion. The oxide of lead should be at least twice the weight of the salt. This would have answered extremely well, had there been an adequate and regular demand for the pigment. At present, we understand, the greater part of the carbonate of soda in the market is furnished by decomposing the sulphate of soda left after the muriatic acid is expelled in the usual way of manufacturing it from common salt. Various processes for this purpose were tried in France and made public by the French government, all depending on the principle of decomposing the acid of the sulphate, by charcoal, and at the same time adding some other material to prevent the soda from forming a sulphuret. What they consider as the best, is to mix the sulphate of soda with an equal weight of chalk and rather more than half its weight of charcoal powder, and to expose the mixture in a reverberatory furnace to a heat sufficient to bring them to a state of imperfect liquefaction. Much of the sulphur formed will be expelled in vapour and burned, the mixture being frequently stirred to promote this; and this is continued till the mass on cooling assumes a fine grain. It is then left exposed to a humid atmosphere, and the carbonate of soda may be extracted by lixiviation, the sulphur not consumed having united with the lime. Tinmen's shreds, or old iron, may be employed instead of chalk, in the proportion of 65 parts to 200 of sulphate of soda, and 62 of charcoal; or chalk and iron may be used at the same time in different proportions. The muriate of soda might be decomposed in the first instance by the sulphate of iron, instead of the sulphuric acid. The carbonate of soda thus prepared, however, is not free from sulphur, and Dizé recommends the abstraction of it by adding litharge to the lixivium in a state of ebullition, which will render the alkali pure. Oxide of manganese was substituted in the same way with equal success; and this may be used repeatedly, merely by calcining it after each time to expel the sulphur.

Mr. Accum gives the following method, as having answered extremely well in a soda manufactory in which he was employed:—Five hundred pounds of sulphate of soda, procured from the bleachers, who make a large quantity in preparing their muriatic acid from common salt, were put into an iron boiler with a sufficient quantity of soft water. Into another boiler were put 560 lbs. of good American potash, or 570, if the potash were indifferent, dissolved in about 30 pails of water, or as little as possible. When both were brought to boil, the solution of potash was ladled into that of sulphate of soda, agitating the mixture, and raising the fire as quickly as possible. When the whole boiled, it was ladled into a wooden gutter, that conveyed it to a wooden cistern lined with lead near half an inch thick, in a cool place. Sticks were placed across the cistern, from which slips of sheet lead, two or three inches wide, hung down into the fluid about four inches distant from each other. When the whole was cold, which in winter was in about three days, the fluid was drawn off, the crystalized salt was detached from the slips of lead, and the rock of salt fixed to the bottom was separated by a chisel and mallet. The salt being washed in the same cistern, to free it from impurities, was then returned to the boiler, dissolved in clear water, and evaporated till a strong pellicle formed. Letting it cool till the hand could be dipped into it, it was kept at this temperature as long as pellicles would form over the whole surface, and fall to the bottom. When no more pellicles appeared without blowing on the surface, the fire was put out, and the solution returned into the cistern to crystallize. If the solution be suffered to cool pretty low, very little sulphate of potash will be found mixed with the soda; but the rocky masses met with in the market generally contain a pretty large quantity. In the process above described, the produce of the mixed salt from 100 lbs. of sulphate of soda was in general from 136 to 139 lbs.

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† Why did it not sink? Does salt swim like ice? I question the truth of this account.

Besides its use in seasoning our food, and preserving meat both for domestic consumption and during the longest voyages, and in furnishing us with the muriatic acid and soda, salt forms a glaze for coarse pottery, by being thrown into the oven where it is baked; it improves the whiteness and clearness of glass; it gives greater hardness to soap; in melting metals it preserves their surface from calcination, by defending them from the air, and is employed with advantage in some assays; it is used as a mordant, and for improving certain colours, and enters more or less into many other processes of the arts.

The muriate of strontian has not long been known. Dr. Hope first distinguished it from muriate of barytes. It crystallizes in very slender hexagonal prisms, has a cool pungent taste, without the austerity of the muriate of barytes, or the bitterness of the muriate of lime; is soluble in 0.75 of water at 60°, and to almost any amount in boiling water; is likewise soluble in alcohol, and gives a blood-red colour to its flame.

It has never been found in nature, but may be prepared in the same way as the muriate of barytes.

The muriate of lime has been known by the names of *marine selenite*, *calcareous marine salt*, *muria*, *and fixed sal ammoniac*. It crystallizes in hexaëdral prisms, terminated by acute pyramids; but if the solution be greatly concentrated, and exposed to a low temperature, it is condensed in confused bundles of needly crystals. Its taste is acrid, bitter, and very disagreeable. It is soluble in half its weight of cold water, and by heat in its own water of crystallization. It is one of the most deliquescent salts known; and when deliquesced has been called *oil of lime*. It exists in nature, but neither very abundantly nor very pure. It is formed in chemical laboratories, in the decomposition of muriate of ammonia; and Homberg found, that, if it were urged by a violent heat, till it condensed, on cooling, into a vitreous mass, it emitted a phosphoric light upon being struck by any hard body, in which state it was called *Homberg's phosphorus*.

Hitherto it has been little used except for frigorific mixtures; and with snow it produces a very great degree of cold. Fourcroy, indeed, says he has found it of great utility in obstructions of the lymphatics, and in scrofulous affections.

The muriate of ammonia has long been known by the name of *sal ammonia*, or *ammonic*. It is found native in the neighbourhood of volcanoes, where it is sublimed sometimes nearly pure, and in different parts of Asia and Africa. A great deal is carried annually to Russia and Siberia from Bucharian Tartary; and we formerly imported large quantities from Egypt, but now manufacture it at home. See AMMONIA.

This salt is usually in the form of cakes, with a convex surface on one side, and concave on the other, from being sublimed into large globular vessels; but by solution it may be obtained in regular quadrangular crystals. It is remarkable for possessing a certain degree of ductility, so that it is not easily pulverable. It is soluble in 3½ parts of water at 60°, and in little more than its own weight of boiling water. Its taste is cool, acrid, and bitterish. Its specific gravity is 1.42. It attracts moisture from the air but very slightly.

Muriate of ammonia has been more employed in medicine than it is at present. It is sometimes useful as an auxiliary to the bark in intermittents; in gargles it is beneficial, and externally it is a good discutient. In dyeing it improves or heightens different colours. In tinning and soldering it is employed to preserve the surface of the metals from oxidation. In assaying it discovers iron, and separates it from some of its combinations.

The muriate of magnesia is extremely deliquescent, soluble in an equal weight of water, and difficultly crystallizable It dissolves also in five parts of alcohol. It is decomposable by heat, which expels its acid. Its taste is intensely bitter.

With ammonia this muriate forms a triple salt, crystallizable in little polyedrons, which separate quickly from the water, but are not very regularly formed. Its taste partakes of that of both the preceding salts. The best mode of preparing it, is by mixing a solution of 27 parts of muriate of ammonia with a solution of 73 of muriate of magnesia; but it may be formed by a semi-decomposition of either of these muriates by the base of the other. It is decomposable by heat, and requires six or seven times its weight of water to dissolve it.

Of the muriate of glucine we know but little. It appears to crystallize in very small crystals; to be decomposable by heat; and, dissolved in alcohol and diluted with water, to form a pleasant saccharine liquor.

Muriate of alumina is scarcely crystallizable, as on evaporation it assumes the state of a thick jelly. It has an acid, styptic, acrid taste. It is extremely soluble in water, and deliquescent. Fire decomposes it. It may be prepared by directly combining the muriatic acid with alumina, but the acid always remains in excess.

The muriate of zircon crystallizes in small needles, which are very soluble, attract moisture, and lose their transparency in the air. It has an austere taste, with somewhat of acrimony. It is decomposable by heat. The gallic acid precipitates from its solution, if it be free from iron, a white powder. Carbonate of ammonia, if added in excess, redissolves the precipitate it had before thrown down.

Muriate of yttria does not crystallize when evaporated, but forms a jelly: it dries with difficulty, and deliquesces.

Fourcroy observes, that when siliceous stones, previously fused with potash, are treated with muriatic acid, a limpid solution is formed, which may be reduced to a transparent jelly by slow evaporation. But a boiling heat decomposes the siliceous muriate, and the earth is deposited. The solution is always acid.

* Acid (Muriatic, Oxygenated). See Chlorine.*

* Acid (Muriatic, Oxygenized). This supposed acid was lately described by M. Thenard. He saturated common muriatic acid of moderate strength with deutoxide of barium, reduced into a soft paste by trituration with water. He then precipitated the barytes from the liquid, by adding the requisite quantity of sulphuric acid. He next took this oxygenized muriatic acid, and treated it with deutoxide of barium and sulphuric acid, to oxygenate it anew. In this way he charged it with oxygen as often as 15 times. He thus obtained a liquid acid which contained 32 times its volume of oxygen at the temperature of 68° Fahr. and at the ordinary atmospherical pressure, and only 4½ times its volume of muriatic acid, which gives about 28 equivalent primes of oxygen to one of muriatic acid. For the ratio of oxygen to the acid, by weight, is 1. to 4.6; but by measure the ratio will be as these two numbers respectively divided by the specific gravity of the gases, or as $\frac{1}{1.111}$ to $\frac{46}{1.278}$, which by reduction makes nearly one volume of oxygen, equivalent to four of muriatic acid. Now, the oxygen in the above result, instead of being 1-4th of the volume of the acid gas, was seven times greater, whence we derive the number 28. Still more oxygen may however be added. On putting the above oxygenized acid in contact with sulphate of silver, an insoluble chloride of this metal subsides, and the liquid is oxygenized sulphuric acid. When this is passed through the filter, muriatic acid is added to it, but in smaller quantity than existed in the original oxygenized acid. A quantity of barytes, just sufficient to precipitate the sulphuric acid, is then added. Instantly the oxygen, leaving the sulphuric acid to unite with the muriatic acid, brings that acid to the highest point of oxygenation. Thus we see that we can transfer the whole of the oxygen from one of these acids to the other; and on a little reflection it will be evident, that to obtain sulphuric acid in the highest degree of oxygenation, it will be merely necessary to pour barytes water into oxygenated sulphuric acid, so as to precipitate only a part of the acid.

All these operations, with a little practice, may be performed without the least difficulty. By combining the two methods just described, M. Thenard found that he could obtain oxygenized muriatic acid, containing nearly 16 times as many volumes of oxygen as of muriatic acid, which represents about 64 equivalent primes of the former to one of the latter. This oxygenized acid leaves no residuum when evaporated. It is a very acid, colourless liquid, almost destitute of smell, and powerfully reddens turnsole. When boiled for some time, its oxygen is expelled. It dissolves zinc without effervescence. Its action on the oxide of silver is curious. These two bodies occasion as lively an effervescence as if an acid were poured upon a carbonate. Water and a chloride are formed, while the oxygen is evolved. This oxide enables us to determine the quantity of oxygen present in the oxygenized acid. Pour mercury into a graduated glass tube, leaving a small determinate space, which must be filled with the above acid, invert the tube in mercury, let up oxide of silver diffused in water; instantly the oxygen is separated.

We ought, however, to regard this apparent oxygenation of the acid, merely as the conversion of a portion of its combined water into deutoxide of hydrogen. The same explanation may be extended to the other oxygenized acids of M. Thenard. See Water.*

* **Acid (Chloric).** We place this acid after the muriatic acid, because it has chlorine also for its base. It was first eliminated from the salts containing it by M. Gay-Lussac, and described by him in his admirable memoir on iodine, published in the 91st volume of the *Annales de Chimie*. When a current of chlorine is passed for some time through a solution of barytic earth in warm water, a substance called hyperoxymuriate of barytes by its first discoverer, M. Chenevix, is formed, as well as some common muriate. The latter is separated, by boiling phosphate of silver in the compound solution. The former may then be obtained by evaporation, in fine rhomboidal prisms. Into a dilute solution of this salt, M. Gay-Lussac poured weak sulphuric acid. Though he added only a few drops of acid, not nearly enough to saturate the barytes, the liquid became sensibly acid, and not a bubble of oxygen escaped. By continuing to add sulphuric acid with caution, he succeeded in obtaining an acid liquid entirely free from sulphuric acid and barytes, and not precipitating nitrate of silver. It was chloric acid dissolved in water. Its characters are the following.

This acid has no sensible smell. Its solution in water is perfectly colourless. Its taste is very acid, and it reddens litmus without destroying the colour. It produces no alteration on solution of indigo in sulphuric acid. Light does not decompose it. It may be concentrated by a gentle heat, without undergoing decomposition, or without evaporating. It was kept a long time exposed to the air without sensible diminution of its quantity. When concentrated, it has something of an oily consistency. When exposed to heat, it is partly decomposed into oxygen and chlorine, and partly volatilized without alteration. Muriatic acid decomposes it in the same way, at the common temperature. Sulphurous acid, and sulphuretted hydrogen, have the same property; but nitric acid produces no change upon it. Combined with ammonia, it forms a fulminating salt, formerly described by M. Chenevix. It does not precipitate any metallic solution. It readily dissolves zinc, disengaging hydrogen; but it acts slowly on mercury. It cannot be obtained in the gaseous state. It is composed of 1 volume chlorine + 2.5 oxygen, or, by weight, of 100 chlorine + 111.70 oxygen, if we consider the specific gravity of chlorine to be 2.4866. But if it be called 2.420, as M. Gay-Lussac does in his memoir, it will then come out 100 chlorine + 114.7 oxygen. This last number is however too great, in consequence of estimating the specific gravity of oxygen 1.1111, while M. Gay-Lussac makes it 1.10359. Chloric acid is at any rate a compound of 5 primes of oxygen + 1 of chlorine = 5. + 4.43 by Berzelius, or 5. + 4.45 by Dr. Ure's estimate of the atom of chlorine.

M. Vauquelin, in making phosphate of silver act on the mixed saline solution above described, tried to accelerate its action by dissolving it previously in acetic acid. But on evaporating the chlorate of barytes so obtained to dryness, and exposing about 30 grains to a decomposing heat, a tremendous explosion took place, which broke the furnace, rent a thick platina crucible, and drove its lid into the chimney, where it stuck. It was the employment of acetic acid which occasioned this accident, and therefore it ought never to be used in this way.

To the preceding account of the properties of chloric acid, M. Vauquelin has added the following: Its taste is not only acid, but astringent, and its odour, when concentrated, is somewhat pungent. It differs from chlorine, in not precipitating gelatin. When paper stained with litmus is left for some time in contact with it, the colour is destroyed. Mixed with muriatic acid, water is formed, and both acids are converted into chlorine. Sulphurous acid is converted into sulphuric, by taking oxygen from the chloric acid, which is consequently converted into chlorine.

Chloric acid combines with the bases, and forms the chlorates, a set of salts formerly known by the name of the hyperoxygenized muriates. They may be formed either directly by saturating the alkali or earth with the chloric acid, or by the old process of transmitting chlorine through the solutions of the bases, in Woulfe's bottles. In this case the water is decomposed. Its oxygen unites to one portion of the chlorine, forming chloric acid, while its hydrogen unites to another portion of chlorine, forming muriatic acid; and hence, chlorates and muriates must be contemporaneously generated, and must be afterwards separated by crystallization, or peculiar methods.

The chlorate of potash, or hyperoxymuriate, has been long known. When exposed to a red heat, 100 grains of this salt yield 38.88 of oxygen, and are converted into the chloride of potassium, or the dry muriate. This remainder of 61.12 grains consists of 32.19 potassium and 28.93 chlorine. But 32.19 potassium require 6.50 oxygen, to form the potash which existed in the original chlorate. Therefore, subtracting this quantity from 38.88, we have 32.38 for the oxygen combined with the chlorine, constituting 61.31 of chloric acid, to 38.69 of potash.*

To its compounds we shall proceed, premising, that we are indebted to M. Chenevix for the first accurate description of the chlorates, or hyperoxymuriates.

Chlorate, or hyperoxymuriate of potash, may be procured by receiving chlorine, as it is formed, into a solution of potash. When the solution is saturated, it may be evaporated gently, and the first crystals produced will be the salt desired, this crystallizing before the simple muriate, which is produced at the same time with it. Its crystals are in shining hexaëdral laminæ, or rhomboidal plates. It is soluble in 17 parts of cold water; and, but very sparingly, in alcohol. * Its taste is cooling, and rather unpleasant. Its specific gravity is 2.0. 16 parts of water, at 60°, dissolve one of it, and 2½ of boiling water. The purest oxygen is extracted from this salt, by exposing it to a gentle red heat. One hundred grains yield about 115 cubic inches of gas. It consists of 9.45 chloric acid + 5.95 potash = 15.4, which is the prime equivalent of the salt.* It is not decomposed by the direct rays of the sun. Subjected to distillation in a coated retort, it first fuses, and on increasing the heat, gives out oxygen gas. It is incapable of discharging vegetable colours; but the addition of a little sulphuric acid developes this property. So likewise a few grains of it, added to an ounce of muriatic acid, give it this property. It is decomposed by the sulphuric and nitric acids. If a few grains be dropped into strong sulphuric acid, an offensive smell is produced, resembling that of a brick-kiln, mixed with that of nitrous gas; and if the quantity be large enough, an explosion will ensue. If the vessel be deep, it will be filled with a thick, heavy vapour, of a greenish yellow colour, but not producing the symptoms of catarrh, at least in so violent a degree as the fumes of chlorine. Underneath this vapour is a bright orange-coloured fluid. This vapour inflames alcohol, oil of turpentine, camphor, resin, tallow, elastic gum, and some other inflammable substances, if thrown into it. If the sulphuric acid be poured upon the salt, a violent decrepitation takes place, sometimes, though rarely, accompanied by a flash. M. Chenevix attempted to disengage the chloric acid from this salt, by adding sulphuric acid to it in a retort; but almost as soon as the fire was kindled, an explosion took place, by which a French gentleman present was severely wounded, and narrowly escaped the loss of an eye.

The effects of this salt on inflammable bodies are very powerful. Rub two grains into powder in a mortar, add a grain of sulphur, mix them well by gentle trituration, then collect the powder into a heap, and press upon it suddenly and forcibly with the pestle, a loud detonation will ensue. If the mixture be wrapped in strong paper, and struck with a hammer, the report will be still louder. Five grains of the salt, mixed in the same manner with two and a half of charcoal, will be inflamed by strong trituration, especially if a grain or two of sulphur be added, but without much noise. If a little sugar be mixed with half its weight of the chlorate, and a little strong sulphuric acid poured on it, a sudden and vehement inflammation will ensue; but this experiment requires caution, as well as the following. To one grain of the powdered salt in a mortar, add half a grain of phosphorus, it will detonate, with a loud report, on the gentlest trituration. In this experiment the hand should be defended by a glove, and great care should be taken that none of the phosphorus get into the eyes. Phosphorus may be inflamed by it under water, by putting into a wine glass one part of phosphorus and two of the chlorate, nearly filling the glass with water, and then pouring in through a glass tube reaching to the bottom, three or four parts of sulphuric acid. This experiment, too, is very hazardous to the eyes. If olive or linseed oil be taken instead of phosphorus, it may be inflamed by similar means on the surface of the water. This salt should not be kept mixed with sulphur, or perhaps any inflammable substance, as in this state it has been known to detonate spontaneously. As it is the common effect of mixtures of this salt with inflammable substances of every kind, to take fire on being projected into the stronger acids, M. Chenevix tried the experiment with it mixed with diamond powder in various proportions, but without success.

Chlorate of soda may be prepared in the same manner as the preceding, by substituting soda for potash; but it is not easy to obtain it separate, as it is nearly as soluble as the muriate of soda, requiring only 3 parts of cold water. * Vauquelin formed it, by saturating chloric acid with soda; 500 parts of the dry carbonate yielding 1100 parts of crystallized chlorate. It consists of 3.95 soda + 9.45 acid = 13.4, which is its prime equivalent.* It crystallizes in square plates, produces a sensation of cold in the mouth, and a saline taste; is slightly deliquescent, and in its other properties resembling the chlorate of potash.

Barytes appears to be the next base in order of affinity for this acid. The best method of forming it is to pour hot water on a large quantity of this earth, and to pass a current of chlorine through the liquid kept warm, so that a fresh portion of barytes may be taken up as the former is saturated. This salt is soluble in about four parts of cold water, and less of warm, and crystallizes like the simple muriate. It may be obtained, however, by the agency of double affinity; for phosphate of silver boiled in the solution will decompose the simple muriate, and the muriate of silver and phosphate of barytes being insoluble, will both fall down and leave the chlorate in solution alone. The phosphate of silver employed in this process must be perfectly pure, and not the least contaminated with copper.

The chlorate of strontites may be obtained in the same manner. It is deliquescent, melts immediately in the mouth and produces cold; is more soluble in alcohol than the simple muriate, and crystallizes in needles.

The chlorate of lime, obtained in a similar way, is extremely deliquescent, liquefies at a low heat, is very soluble in alcohol, produces much cold in solution, and has a sharp bitter taste.

Chlorate of ammonia is formed by double affinity, the carbonate of ammonia decomposing the earthy salts of this genus, giving up its carbonic acid to their base, and combining with their acid into chlorate of ammonia, which may be obtained by evaporation. It is very soluble both in water and alcohol, and decomposed by a moderate heat.

The chlorate of magnesia much resembles that of lime.

To obtain chlorate of alumina, M. Chenevix put some alumina, precipitated from the muriate, and well washed, but still moist, into a Woulfe's apparatus, and treated it as the other earths. The alumina shortly disappeared; and on pouring sulphuric acid into the liquor, a strong smell of chloric acid was perceivable; but on attempting to obtain the salt pure by means of phosphate of silver, the whole was decomposed, and nothing but chlorate of silver was found in the solution. M. Chenevix adds, however, that the aluminous salt appears to be very deliquescent, and soluble in alcohol.

* Acid (Perchloric). If about 3 parts of sulphuric acid be poured on one of chlorate of potash in a retort, and after the first violent action is over, heat be gradually applied, to separate the deutoxide of chlorine, a saline mass will remain, consisting of bisulphate of potash and perchlorate of potash. By one or two crystallizations, the latter salt may be separated from the former. It is a neutral salt, with a taste somewhat similar to the common muriate of potash. It is very sparingly soluble in cold water, since at 60°, only $\frac{1}{65}$ is dissolved; but in boiling water it is more soluble. Its crystals are elongated octahedrons. It detonates feebly when triturated with sulphur in a mortar. At the heat of 412°, it is resolved into oxygen and muriate of potash, in the proportion of 46 of the former to 54 of the latter. Sulphuric acid, at 280°, disengages the perchloric acid. For these facts science is indebted to Count Von Stadion. It seems to consist of 7 primes of oxygen, combined with 1 of chlorine, or $7.0 + 4.45$. These curious discoveries has been lately verified by Sir H Davy. The other perchlorates are not known.

Before leaving the acids of chlorine, we shall describe the ingenious method employed by Mr. Wheeler to procure chloric acid from the chlorate of potash. He mixed a warm solution of this salt with one of fluosilicic acid. He kept the mixture moderately hot for a few minutes, and to ensure the perfect decomposition of the salt, added a slight excess of the acid. Aqueous solution of ammonia will show, by the separation of silica, whether any of the fluosilicic acid be left after the decomposition of the chlorate. Thus we can effect its complete decomposition. The mixture becomes turbid, and fluosilicate of potash is precipitated abundantly in the form of a gelatinous mass. The supernatant liquid will then contain nothing but chloric acid, contaminated with a small quantity of fluosilicic. This may be removed by the cautious addition of a small quantity of solution of chlorate. Or after filtration, the whole acid may be neutralized by carbonate of barytes, and the chlorate of that earth being obtained in crystals, is employed to procure the acid, as directed by M. Gay-Lussac.*

Acid (Nitric.) The two principal constituent parts of our atmosphere, when in certain proportions, are capable, under particular circumstances, of combining chemically into one of the most powerful acids, the nitric. If these gases be mixed in a proper proportion in a glass tube about a line in diameter, over mercury, and a series of electric shocks be passed through them for some hours, they will form nitric acid; or, if a solution of potash be present with them, nitrate of potash will be obtained. The constitution of this acid may be further proved, analytically, by driving it through a red hot porcelain tube, as thus it will be decomposed into oxygen and nitrogen gases. For all practical purposes, however, the nitric acid is obtained from nitrate of potash, from which it is expelled by sulphuric acid.

Three parts of pure nitrate of potash,† coarsely powdered, are to be put into a glass retort, with two of strong sulphuric acid. This must be cautiously added, taking care to avoid the fumes that arise. Join to the retort a tubulated receiver of large capacity, with an adopter interposed, and lute the junctures with glazier's putty. In the tubulure fix a glass tube, terminating in another large receiver, in which is a small quantity of water; and, if you wish to collect the gaseous products, let a bent glass tube from this receiver communicate with a pneumatic trough. Apply heat to the retort by means of a sand bath. The first product that passes into the receiver is generally red and fuming; but the appearances gradually diminish, till the acid comes over pale, and even colourless, if the materials used were clean. After this it again becomes more and more red and fuming, till the end of the operation; and the whole mingled together will be of a yellow or orange colour.

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† Deprived of its water of crystallization by heating it nearly red hot in an iron pan.

* Empty the receiver, and again replace it. Then introduce by a small funnel, very cautiously, one part of boiling water in a slender stream, and continue the distillation. A small quantity of a weaker acid will thus be obtained, which can be kept apart. The first will have a specific gravity of about 1.500, if the heat have been properly regulated, and if the receiver was refrigerated by cold water or ice. Acid of that density, amounting to two-thirds of the weight of the nitre, may thus be procured. But commonly the heat is pushed too high, whence more or less of the acid is decomposed, and its proportion of water uniting to the remainder, reduces its strength. It is not profitable to use a smaller proportion of sulphuric acid, when a concentrated nitric is required. But when only a dilute acid, called in commerce *aquafortis*, is required, then less sulphuric acid will suffice, provided a portion of water be added. One hundred parts of good nitre, sixty of strong sulphuric acid, and twenty of water, form economical proportions.*

In the large way, and for the purposes of the arts, extremely thick cast iron or earthen retorts are employed, to which an earthen head is adapted, and connected with a range of proper condensers. The strength of the acid too is varied, by putting more or less water in the receivers. The nitric acid thus made generally contains sulphuric acid, and also muriatic, from the impurity of the nitrate employed. If the former, a solution of nitrate of barytes will occasion a white precipitate; if the latter, nitrate of silver will render it milky. The sulphuric acid may be separated by a second distillation from very pure nitre, equal in weight to an eighth of that originally employed; or by precipitating with nitrate of barytes, decanting the clear liquid, and distilling it. The muriatic acid may be separated by proceeding in the same way with nitrate of silver, or with litharge, decanting the clear liquor, and re-distilling it, leaving an eighth or tenth part in the retort. The acid for the last process should be condensed as much as possible, and the re-distillation conducted very slowly; and if it be stopped when half is come over, beautiful crystals of muriate of lead will be obtained on cooling the remainder, if litharge be used, as M. Steinacher informs us; who also adds, that the vessels should be made to fit tight by grinding, as any lute is liable to contaminate the product.

As this acid still holds in solution more or less nitrous gas, it is not in fact nitric acid, but a kind of nitrous: it is therefore necessary to put it into a retort, to which a receiver is added, the two vessels not being luted, and to apply a very gentle heat for several hours, changing the receiver as soon as it is filled with red vapours. The nitrous gas will thus be expelled, and the nitric acid will remain in the retort as limpid and colourless as water. It should be kept in a bottle secluded from the light, otherwise it will lose part of its oxygen.

What remains in the retort is a bisulphate of potash, from which the superfluous acid may be expelled by a pretty strong heat, and the residuum, being dissolved and crystallized, will be sulphate of potash.

As nitric acid in a fluid state is always mixed with water, different attempts have been made to ascertain its strength, or the quantity of real acid contained in it. Mr. Kirwan supposed, that the nitrate of soda contained the pure acid undiluted with water, and thus calculated its strength from the quantity requisite to saturate a given portion of soda. Sir H. Davy more recently took the acid in the form of gas as the standard, and found how much of this is contained in an acid of a given specific gravity in the liquid state.

* Mr. Kirwan gave 68 as the quantity of real acid in 100 of the liquid acid of specific gravity 1.500; Sir H. Davy's determination was 91; Dr. Wollaston's, as inferred from the experiments of Mr. R. Philips, 75; and Mr. Dalton's corrected result from Kirwan's table, was 68. In this state of discordance Dr. Ure performed a series of experiments, with the view of determining the constitution of liquid nitric acid, and published an account of them, with some new tables, in the fourth and sixth volumes of the Journal of Science and the Arts.

From regular prisms of nitre, he procured by slow distillation, with concentrated oil of vitriol, nitric acid; which by the tests of nitrates of silver and of barytes, was found to be pure. Only the first portion that came over was employed for the experiments. It was nearly colourless, and had a specific gravity of 1.500. A re-distilled and colourless nitric acid, prepared in London, was also used for experiments of verification, in estimating the quantity of dry acid in liquid acid of a known density.

The above acid of 1.500 being mixed in numbered phials, with pure water, in the different proportions of 95 + 5, 90 + 10, 80 + 20, &c. he obtained, after due agitation, and an interval of 24 hours, liquids whose specific gravities, at 60° Fahrenheit, were determined by means of an accurate balance, with a narrow-necked glass globe of known capacity. By considering the series of numbers thus obtained, he discovered the geometrical law which regulates them. The specific gravity of dilute acid, containing 10 parts in the 100 of that whose density is 1.500, is 1.054. Taking this number as the root, its successive powers will give us the successive densities, at the terms of 20, 30, 40, &c. per cent. Thus $1.054^2 = 1.111$ is the specific gravity corresponding to 20 of the strong liquid acid + 80 water; $1.054^3 = 1.171$ is that for 30 per cent. of strong acid; $1.054^4 = 1.234$ is the specific gravity at 40 per cent. The specific gravities are therefore a series of numbers in geometrical progression, corresponding to the terms of dilution, another series in arithmetical progression, exactly as he had shown in the 7th number of the Journal of Science with regard to sulphuric acid. Hence if one term be given, the whole series may be found. On uniting the strong acid with water, a considerable condensation of volume takes place. The *maximum* condensation occurs, when 58 of acid are mixed with 42 of water. Above this point, the curve of condensation has a contrary flexure; and therefore a small modification must be made on the root 1.054, in order to obtain with final accuracy, in the higher part of the range, the numerical powers which represent the specific gravities. The modification is however very simple. To obtain the number for 50 per cent, the root is 1.053; and for each decade up to 70, the root must be diminished by 0.002. Thus for 60, it will become 1.051, and for 70, 1.049. Above this we shall obtain a precise correspondence with experiment, up to 1.500 sp. gravity, if for each successive decade we subtract 0.0025 from the last diminished root, before raising it to the desired power, which represents the *per centage* of liquid acid.

It is established by the concurring experiments of Sir H. Davy and M. Gay-Lussac, that dry nitric acid is a compound of 2½ volumes of oxygen combined with 1 of nitrogen; of which the weights are $2.5 \times 1.111 = 2.777$ for the proportion of oxygen, and 0.9722 for that of nitrogen; and in 100 parts, of 73$\frac{1}{3}$ of the former + 26$\frac{2}{3}$ of the latter. But nitrogen combines with several inferior proportions of oxygen, which are all multiples of its prime equivalent 1.0; and the present compound is exactly represented by making 1 prime of nitrogen = 1.75, and 5 of oxygen = 5.0; whence the acid prime is the sum of these two numbers, or 6.75. Now this result deduced from its constituents, coincides perfectly with that derived from the quantity in which this acid saturates definite quantities of the salifiable bases, potash, soda, lime, &c. There can be no doubt, therefore, that the prime equivalent of the acid is 6.75; and as little that it consists of 5 parts of oxygen and 1.75 of nitrogen. Possessed of these data, we may perhaps see some reason why the greatest condensation of volume, in diluting strong liquid acid, should take place with 58 of it, and 42 of water. Since 100 parts of acid of 1.500 contain, by Dr. Ure's experiments, 79.7 of dry acid, therefore acid of the above dilution will contain 46 dry acid, and 54 water; or reducing the numbers to prime proportions, we have the ratio of 6.75 to 7.875, being that of one prime of real acid to 7 primes of water. But we have seen that the real acid prime, is made up of 1 of nitrogen associated by chemical affinity with 5 of oxygen. Now imagine a figure, in which the central prime of nitrogen is surrounded by 5 of oxygen. To the upper and under surface of the nitrogen let a prime of water be attached; and one also to each of the primes of oxygen. We have thus the 7 primes distributed in the most compact and symmetrical manner. By this *hypothesis*, we can understand how the elements of acid and water may have such a collocation and proportion, as to give the utmost efficacy to their reciprocal attractions, whence the *maximum* condensation will result. A striking analogy will be found in the dilution of sulphuric acid.

If on 58 parts by weight of acid of 1.500, we pour cautiously 42 of water in a graduated measure, of which the whole occupies 100 divisions, and then mix them intimately, the temperature will rise from 60° to 140°, and after cooling to 60° again, the volume will be found only 92.65. No other proportion of water and acid causes the evolution of so much heat. When 90 parts of the strong acid are united with 10 of water, 100 in volume become 97; and when 10 parts of the same acid are combined with 90 of water, the resulting volume is 98. It deserves notice, that 80 of acid + 20 water, and 30 of acid + 70 water, each gives a dilute acid, whose degree of condensation is the same, namely, 100 measures become 94.8.

TABLE of Nitric Acid, by Dr. Ure.

Sp. Gr.	*Liq. Acid in* 100	*Dry Acid in* 100.	*Sp. Gr.*	*Liq. Acid in* 100	*Dry Acid in* 100.	*Sp. Gr.*	*Liq. Acid in* 100	*Dry Acid in* 100.	*Sp. Gr.*	*Liq. Acid in* 100	*Dry Acid in* 100.
1.5000	100	79.700	1.4189	75	59.775	1.2947	50	39.850	1.1403	25	19.925
1.4980	99	78.903	1.4147	74	58.978	1.2887	49	39.053	1.1345	24	19.128
1.4960	98	78.106	1.4107	73	58.181	1.2826	48	38.256	1.1286	23	18.331
1.4940	97	77.309	1.4065	72	57.384	1.2765	47	37.459	1.1227	22	17.534
1.4910	96	76.512	1.4023	71	56.587	1.2705	46	36.662	1.1168	21	16.737
1.4880	95	75.715	1.3978	70	55.790	1.2644	45	35.865	1.1109	20	15.940
1.4850	94	74.918	1.3945	69	54.993	1.2583	44	35.068	1.1051	19	15.143
1.4820	93	74.121	1.3882	68	54.196	1.2523	43	34.271	1.0993	18	14.346
1.4790	92	73.324	1.3833	67	53.399	1.2462	42	33.474	1.0935	17	13.549
1.4760	91	72.527	1.3783	66	52.602	1.2402	41	32.677	1.0878	16	12.752
1.4730	90	71.730	1.3732	65	51.805	1.2341	40	31.880	1.0821	15	11.955
1.4700	89	70.933	1.3681	64	51.068	1.2277	39	31.083	1.0764	14	11.158
1.4670	88	70.136	1.3630	63	50.211	1.2212	38	30.286	1.0708	13	10.361
1.4640	87	69.339	1.3579	62	49.414	1.2148	37	29.489	1.0651	12	9.564
1.4600	86	68.542	1.3529	61	48.617	1.2084	36	28.692	1.0595	11	8.767
1.4570	85	67.745	1.3477	60	47.820	1.2019	35	27.895	1.0540	10	7.970
1.4530	84	66.948	1.3427	59	47.023	1.1958	34	27.098	1.0485	9	7.173
1.4500	83	66.155	1.3376	58	46.226	1.1895	33	26.301	1.0430	8	6.376
1.4460	82	65.354	1.3323	57	45.429	1.1833	32	25.504	1.0375	7	5.579
1.4424	81	64.557	1.3270	56	44.632	1.1770	31	24.707	1.0320	6	4.782
1.4385	80	63.760	1.3216	55	43.835	1.1709	30	23.910	1.0267	5	3.985
1.4346	79	62.963	1.3163	54	43.038	1.1648	29	23.113	1.0212	4	3.188
1.4306	78	62.166	1.3110	53	42.241	1.1587	28	22.316	1.0159	3	2.391
1.4269	77	61.369	1.3056	52	41.444	1.1526	27	21.519	1.0106	2	1.594
1.4228	76	60.572	1.3001	51	40.647	1.1465	26	20.722	1.0053	1	0.797

The column of dry acid shows the weight which any salifiable base would gain, by uniting with 100 parts of the liquid acid of the corresponding specific gravity. But it may be proper here to observe, that Sir H. Davy, in extending his views relative to the constitution of the dry muriates, to the nitrates, has suggested, that the latter when dry may be considered as consisting, not of a dry nitric acid combined with the salifiable oxide, but of the oxygen and nitrogen of the nitric acid with the metal itself in triple union. A view of his reasoning will be found under the article Salt. He regards liquid nitric acid at its utmost density as a compound of 1 prime of hydrogen, 1 of nitrogen, and 6 of oxygen.*

The strongest acid that Mr. Kirwan could procure at 60° was 1.5543; but Rouelle professes to have obtained it of 1.583.

Nitric acid should be of the specific gravity of 1.5, or a little more, and colourless.

* That of Mr. Kirwan seems to have consisted of one prime of real acid and one of water, when the suitable corrections are made; but no common chemical use requires it of such a strength. The following table of boiling points has been given by Mr. Dalton.

Acid of sp. gr.	boils at
1.50	210°
1.45	240
1.42	248
1.40	247
1.35	242
1.30	236
1.20	226
1.15	219

At 1.42 specific gravity it distils unaltered. Stronger acid than that becomes weaker, and weaker acid stronger, by boiling. When the strong acid is cooled down to—60°, it concretes, by slight agitation, into a mass of the consistence of butter.

This acid is eminently corrosive, and hence its old name of *aquafortis*. Its taste is sour and acrid It is a deadly poison when introduced into the stomach in a concentrated state; but when greatly diluted, it may be swallowed without inconvenience. It is often contaminated, through negligence or fraud in the manufacturer, with sulphuric and muriatic acids. Nitrate of lead detects both, or nitrate of barytes may be employed to determine the quantity of sulphuric acid, and nitrate of silver that of the muriatic. The latter proceeds from the crude nitre usually containing a quantity of common salt.*

When it is passed through a red hot porcelain tube, it is resolved into oxygen and nitrogen, in the proportion above stated. It retains its oxygen with little force, so that it is decomposed by all combustible bodies. Brought into contact with hydrogen gas at a high temperature, a violent detonation ensues, so that this must not be done without great caution. It inflames essential oils, as those of turpentine and cloves, when suddenly poured on them; but, to perform this experiment with safety, the acid must be poured out of a bottle tied to the end of a long stick, otherwise the operator's face and eyes will be greatly endangered. If it be poured on perfectly dry charcoal powder, it excites combustion, with the emission of copious fumes. By boiling it with sulphur it is decomposed, and its oxygen, uniting with the sulphur, forms sulphuric acid. Chemists in general agree, that it acts very powerfully on almost all the metals; but Baumé has asserted, that it will not dissolve tin, and Dr. Woodhouse of Pennsylvania affirms, that in a highly concentrated and pure state it acts not at all on silver, copper, or tin though, with the addition of a little water, its action on them is very powerful.

Acid which takes up $\frac{418}{1000}$ths of its weight of marble, freezes, according to Mr. Cavendish, at—2°. When it can dissolve $\frac{561}{1000}$, it requires to be cooled to—41°.6 before congelation; and when so much diluted as to take up only $\frac{276}{1000}$, it congeals at—40°.3. The first has a specific gravity of 1.330 nearly, and consists of 1 prime of dry acid + 7 of water; the second has a specific gravity of 1.420, and contains exactly one prime of dry acid + four of water; while the third has a specific gravity of 1.215, consisting of one prime of acid + 14 of water. We perceive, that the liquid acid of 1.420, composed of 4 primes of water + one of dry acid, possesses the greatest power of resisting the influence of temperature to change its state. It requires the maximum heat to boil it, when it distils unchanged; and the maximum cold to effect its congelation.*

It has already been observed, that the nitric acid, when first distilled over, holds in solution a portion of nitric oxide, which is greater in proportion as the heat has been urged toward the end, and much increased by even a small portion of inflammable matter, should any have been present. The colour of the acid, too, is affected by the quantity of nitric oxide it holds, and Sir H. Davy has given us the following table of proportions answering to its different hues.

Colour.	Real Acid.	Nitric Oxide.	Water.
Pale yellow	90.5	1.2	8.3
Bright yellow	88.94	2.96	8.10
Dark orange	86.84	5.56	7.6
Light olive	86.0	6.45	7.55
Dark olive	85.4	7.1	7.5
Bright green	84.8	7.76	7.44
Blue green	84.6	8.	7.4

But these colours are not exact indications of the state of the acid, for an addition of water will change the colour into one lower in the scale, so that a considerable portion of water will change the dark orange to a blue green.

The nitric acid is of considerable use in the arts. It is employed for etching on copper; as a solvent of tin to form with that metal a mordant for some of the finest dyes; in metallurgy and assaying; in various chemical processes, on account of the facility with which it parts with oxygen and dissolves metals; in medicine as a tonic, and as a substitute for mercurial preparations in syphilis and affections of the liver; as also in form of vapour to destroy contagion. For the purposes of the arts it is commonly used in a diluted state, and contaminated with the sulphuric and muriatic acids, by the name of *aquafortis*. This is generally prepared by mixing common nitre with an equal weight of sulphate of iron, and half its weight of the same sulphate calcined, and distilling the mixture; or by mixing nitre with twice its weight of dry powdered clay, and distilling in a reverberatory furnace. Two kinds are found in the shops, one called *double aquafortis*, which is about half the strength of nitric acid; the other simply *aquafortis*, which is half the strength of the double.

A compound made by mixing two parts of the nitric acid with one of muriatic, known formerly by the name of *aqua regia*, and now by that of *nitro-muriatic acid*, has the property of dissolving gold and platina. On mixing the two acids, heat is given out, an effervescence takes place, and the mixture acquires an orange colour. This is likewise made by adding gradually to an ounce of powdered muriate of ammonia, four ounces of double aquafortis, and keeping the mixture in a sand-heat till the salt is dissolved; taking care to avoid the fumes, as the vessel must be left open; or by distilling nitric acid with an equal weight, or rather more, of common salt.

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* Proust has ascertained, that acid having the specific gravity 1.48, has no more action on tin than on sand, while acid somewhat stronger or weaker acts furiously on the metal. Now, acid of 1.485, by Dr. Ure's table, consists of one prime of real acid united with two of water, constituting, it would thus appear, a peculiarly powerful combination.

* On this subject we are indebted to Sir H. Davy for some excellent observations, published by him in the first volume of the Journal of Science. If strong *nitrous* acid, saturated with nitrous gas, be mixed with a saturated solution of muriatic acid gas, no other effect is produced than might be expected from the action of nitrous acid of the same strength on an equal quantity of water; and the mixed acid so formed has no power of action on gold or platina. Again, if muriatic acid gas, and nitrous gas in equal volumes, be mixed together over mercury, and half a volume of oxygen be added, the immediate condensation will be more than might be expected from the formation of nitrous acid gas. And when this is decomposed, or absorbed by the mercury, the muriatic acid gas is found unaltered, mixed with a certain portion of nitrous gas.

It appears then that *nitrous* acid, and muriatic acid gas, have no chemical action on each other. If *colourless nitric* acid, and muriatic acid of commerce, be mixed together, the mixture immediately becomes yellow, and gains the power of dissolving gold and platinum. If it be gently heated, pure chlorine arises from it, and the colour becomes deeper. If the heat be longer continued, chlorine still rises, but mixed with nitrous acid gas. When the process has been very long continued till the colour becomes very deep, no more chlorine can be procured, and it loses its power of acting upon platinum and gold. It is now *nitrous* and muriatic acid. It appears then from these observations, which have been very often repeated, that nitro-muriatic acid owes its peculiar properties to a mutual decomposition of the nitric and muriatic acids; and that water, chlorine, and nitrous acid gas, are the results. Though nitrous gas and chlorine have no action on each other when perfectly dry, yet if water be present there is an immediate decomposition, and nitrous acid and muriatic acid are formed. 118 parts of strong liquid nitric acid being decomposed in this case, yield 67 of chlorine. *Aqua regia* does not oxidize gold and platina. It merely causes their combination with chlorine.

A bath made of nitro-muriatic acid, diluted so much as to taste no sourer than vinegar, or of such a strength as to prick the skin a little, after being exposed to it for twenty minutes or half an hour, has been introduced by Dr. Scott of Bombay as a remedy in chronic syphilis, a variety of ulcers, and diseases of the skin, chronic hepatitis, bilious dispositions, general debility, and languor. He considers every trial as quite inconclusive, where a ptyalism, some affection of the gums, or some very evident constitutional effect, has not arisen from it. The internal use of the same acid has been recommended to be conjoined with that of the partial or general bath.*

With the different bases the nitric acid forms nitrates.

The nitrate of barytes, when perfectly pure, is in regular octaëdral crystals, though it is sometimes obtained in small shining scales. It may be prepared by uniting barytes directly with nitric acid, or by decomposing the carbonate or sulphuret of barytes with this acid. Exposed to heat it decrepitates, and at length gives out its acid, which is decomposed; but if the heat be urged too far, the barytes is apt to vitrify with the earth of the crucible. It is soluble in 12 parts of cold, and 3 or 4 of boiling water. It is said to exist in some mineral waters. * It consists of 6.75 acid + 9.75, or 9.7 base.*

The nitrate of potash is the salt well known by the name of *nitre* or *saltpetre*. It is found ready formed in the East Indies, in Spain, in the kingdom of Naples, and elsewhere, in considerable quantities; but nitrate of lime is still more abundant. Far the greater part of the nitrate made use of is produced by a combination of circumstances which tend to compose and condense nitric acid. This acid appears to be produced in all situations, where animal matters are completely decomposed, with access of air and of proper substances with which it can readily combine. Grounds frequently trodden by cattle and impregnated with their excrements, or the walls of inhabited places where putrid animal vapours abound, such as slaughter-houses, drains, or the like, afford nitre by long exposure to the air. Artificial nitre beds are made by an attention to the circumstances in which this salt is produced by nature. Dry ditches are dug, and covered with sheds, open at the sides, to keep off the rain: these are filled with animal substances—such as dung, or other excrements, with the remains of vegetables, and old mortar, or other loose calcareous earth; this substance being found to be the best and most convenient receptacle for the acid to combine with. Occasional watering, and turning up from time to time, are necessary, to accelerate the process, and increase the surfaces to which the air may apply; but too much moisture is hurtful. When a certain portion of nitrate is formed, the process appears to go on more quickly; but a certain quantity stops it altogether, and after this cessation the materials will go on to furnish more, if what is formed be extracted by lixiviation. After a succession of many months, more or less, according to the management of the operation, in which the action of a regular current of fresh air is of the greatest importance, nitre is found in the mass. If the beds contained much vegetable matter, a considerable portion of the nitrous salt will be common saltpetre, but, if otherwise, the acid will, for the most part, be combined with the calcareous earth. * It consists of 6.75 acid + 5.95 potash.*

To extract the saltpetre from the mass of earthy matter, a number of large casks are prepared, with a cock at the bottom of each, and a quantity of straw within, to prevent its being stopped up. Into these the matter is put, together with wood-ashes, either strewed at top, or added during the filling. Boiling water is then poured on, and suffered to stand for some time; after which it is drawn off, and other water added in the same manner, as long as any saline matter can be thus extracted. The weak brine is heated, and passed through other tubs, until it becomes of considerable strength. It is then carried to the boiler, and contains nitre and other salts; the chief of which is common culinary salt, and sometimes muriate of magnesia. It is the property of nitre to be much more soluble in hot than cold water; but common salt is very nearly as soluble in cold as in hot water. Whenever, therefore, the evaporation is carried by boiling to a certain point, much of the common salt will fall to the bottom, for want of water to hold it in solution, though the nitre will remain suspended by virtue of the heat. The common salt thus separated is taken out with a perforated ladle, and a small quantity of the fluid is cooled, from time to time, that its concentration may be known by the nitre which crystallizes in it. When the fluid is sufficiently evaporated, it is taken out and cooled, and great part of the nitre separates in crystals; while the remaining common salt continues dissolved, because equally soluble in cold and in hot water. Subsequent evaporation of the residue will separate more nitre in the same manner. * By the suggestion of Lavoisier, a much simpler plan was adopted; reducing the crude nitre to powder, and washing it twice with water.*

This nitre, which is called nitre of the first boiling, contains some common salt; from which it may be purified by solution in a small quantity of water, and subsequent evaporation; for the crystals thus obtained are much less contaminated with common salt than before; because the proportion of water is so much larger, with respect to the small quantity contained by the nitre, that very little of it will crystallize. For nice purposes, the solution and crystallization of nitre are repeated four times. The crystals of nitre are usually of the form of six-sided flattened prisms, with diëdral summits. Its taste is penetrating; but the cold produced by placing the salt to dissolve in the mouth is such as to predominate over the real taste at first. Seven parts of water dissolve two of nitre, at the temperature of sixty degrees; but boiling water dissolves its own weight. 100 parts of alcohol, at a heat of 176°, dissolve only 2.9.

On being exposed to a gentle heat, nitre fuses; and in this state being poured into moulds, so as to form little round cakes, for balls, it is called *sal prunella*, or *crystal mineral*. This at least is the way in which this salt is now usually prepared, conformably to the directions of Boerhaave; though in most dispensatories a twenty-fourth part of sulphur was directed to be deflagrated on the nitre before it was poured out. This salt should not be left on the fire after it has entered into fusion, otherwise it will be converted into a *nitrite* of potash. If the heat be increased to redness, the acid itself is decomposed, and a considerable quantity of tolerably pure oxygen gas is evolved, succeeded by nitrogen.

This salt powerfully promotes the combustion of inflammable substances. Two or three parts mixed with one of charcoal, and set on fire, burn rapidly; azote and carbonic acid gas are given out, and a small portion of the latter is retained by the alkaline residuum, which was formerly called *clyssus of nitre*. Three parts of nitre, two of subcarbonate of potash, and one of sulphur, mixed together in a warm mortar, form the *fulminating powder;* a small quantity of which, laid on a fire-shovel, and held over the fire till it begins to melt, explodes with a loud sharp noise. Mixed with sulphur and charcoal, it forms *gunpowder*. See Gunpowder.

Three parts of nitre, one of sulphur, and one of fine saw-dust, well mixed, constitute what is called the powder of fusion. If a bit of base copper be folded up and covered with this powder in a walnut-shell, and the powder be set on fire with a lighted paper, it will detonate rapidly, and fuse the metal into a globule of sulphuret, without burning the shell.

If nitrate of potash be heated in a retort with half its weight of solid phosphoric or boracic acid, as soon as this acid begins to enter into fusion, it combines with the potash, and the nitric acid is expelled, accompanied with a small portion of oxygen gas and nitric oxide.

Silex, alumina, and barytes, decompose this salt in a high temperature by uniting with its base. The alumina will effect this even after it has been made into pottery.

The uses of nitre are various. Beside those already indicated, it enters into the composition of fluxes, and is extensively employed in metallurgy; it serves to promote the combustion of sulphur in fabricating its acid; it is used in the art of dyeing; it is added to common salt for preserving meat, to which it gives a red hue; it is an ingredient in some frigorific mixtures; and it is prescribed in medicine, as cooling, febrifuge, and diuretic; and some have recommended it mixed with vinegar as a very powerful remedy for the sea scurvy.

Nitrate of soda, formerly called *cubic* or *quadrangular nitre*, approaches in its properties to the nitrate of potash; but differs from it in being somewhat more soluble in cold water, though less in hot, which takes up little more than its own weight; in being inclined to attract moisture from the atmosphere; and in crystallizing in rhombs, or rhomboidal prisms. It may be prepared by saturating soda with the nitric acid; by precipitating nitric solutions of the metals, or of the earths, except barytes, by soda; by lixiviating and crystallizing the residuum of common salt distilled with three-fourths its weight of nitric acid; or by saturating the mother waters of nitre with soda instead of potash.

This salt has been considered as useless; but professor Proust says, that five parts of it, with one of charcoal and one of sulphur, will burn three times as long as common powder, so as to form an economical composition for fire-works. *It consists of 6.75 acid + 3.95 soda.*

Nitrate of strontian may be obtained in the same manner as that of barytes, with which it agrees in the shape of its crystals, and most of its properties. It is much more soluble, however, requiring but four or five parts of water according to Vauquelin, and only an equal weight according to Mr. Henry. Boiling water dissolves nearly twice as much as cold. Applied to the wick of a candle, or added to burning alcohol, it gives a deep red colour to the flame. On this account it may be useful, perhaps, in the art of pyrotechny. *It consists of 6.75 acid + 6.5 strontian.*

Nitrate of lime, the *calcareous nitre* of older writers, abounds in the mortar of old buildings, particularly those that have been much exposed to animal effluvia, or processes in which azote is set free. Hence it abounds in nitre beds, as was observed when treating of the nitrate of potash. It may also be prepared artificially, by pouring dilute nitric acid on carbonate of lime. If the solution be boiled down to a sirupy consistence, and exposed in a cool place, it crystallizes in long prisms, resembling bundles of needles diverging from a centre. These are soluble, according to Henry, in an equal weight of boiling water, and twice their weight of cold; soon deliquesce on exposure to the air, and are decomposed to a red heat. Fourcroy says, that cold water dissolves four times its weight, and that its own water of crystallization is sufficient to dissolve it at a boiling heat. It is likewise soluble in less than its weight of alcohol. By evaporating the aqueous solution to dryness, continuing the heat till the nitrate fuses, keeping it in this state five or ten minutes, and then pouring it into an iron pot previously heated, we obtain *Baldwin's phosphorus.* This, which is perhaps more properly *nitrite of lime*, being broken to pieces, and kept in a phial closely stopped, will emit a beautiful white light in the dark, after having been exposed some time to the rays of the sun. At present no use is made of this salt, except for drying some of the gases by attracting their moisture; but it might be employed instead of the nitrate of potash for manufacturing aquafortis.

The nitrate of ammonia possesses the property of exploding, and being totally decomposed, at the temperature of 600°; whence it acquired the name of *nitrum flammans*. The readiest mode of preparing it is by adding carbonate of ammonia to dilute[†] nitric acid till saturation takes place. If this solution be evaporated in a heat between 70° and 100°, and the evaporation not carried too far, it crystallizes in hexaëdral prisms terminating in very acute pyramids: if the heat rise to 212°, it will afford, on cooling, long fibrous silky crystals: if the evaporation be carried so far as for the salt to concrete immediately on a glass rod by cooling, it will form a compact mass. According to Sir H. Davy, these differ but little from each other, except in the water they contain, their component parts being as follows:

	contains acid	ammonia	water
Prismatic	69.5	18.4	12.1
Fibrous	72.5	19.3	8.2
Compact	74.5	19.8	5.7

All these are completely deliquescent, but they differ a little in solubility. Alcohol at 176° dissolves nearly 90.9 of its own weight.

When dried as much as possible without decomposition, it consists of 6.75 acid + 2.13 ammonia + 1.125 water.

The chief use of this salt is for affording nitrous oxide on being decomposed by heat. See NITROGEN, (OXIDE of).

Nitrate of magnesia, *magnesian nitre*, crystallizes in four-sided rhomboidal prisms, with oblique or truncated summits, and sometimes in bundles of small needles. Its taste is bitter, and very similar to that of nitrate of lime, but less pungent. It is fusible, and decomposable by heat, giving out first a little oxygen gas, then nitrous oxide, and lastly nitric acid. It deliquesces slowly. It is soluble in an equal weight of cold water, and in but little more hot, so that it is scarcely crystallizable but by spontaneous evaporation.

[†] I have ascertained, that very strong nitric acid, saturated by carbonate of ammonia, yields the compact nitrate extemporaneously.

The two preceding species are capable of combining into a triple salt, an ammoniaco-magnesian nitrate, either by uniting the two in solution, or by a partial decomposition of either by means of the base of the other. This is slightly inflammable when suddenly heated; and by a lower heat is decomposed, giving out oxygen, azote, more water than it contained, nitrous oxide, and nitric acid. The residuum is pure magnesia. It is disposed to attract moisture from the air, but is much less deliquescent than either of the salts that compose it, and requires eleven parts of water at 60° to dissolve it. Boiling water takes up more, so that it will crystallize by cooling. It consists of 78 parts of nitrate of magnesia, and 22 of nitrate of ammonia.

From the activity of the nitric acid as a solvent of earths in analyzation, the nitrate of glucine is better known than any other of the salts of this new earth. Its form is either pulverulent, or a tenacious or ductile mass. Its taste is at first saccharine, and afterwards astringent. It grows soft by exposure to heat, soon melts, its acid is decomposed into oxygen and azote, and its base alone is left behind. It is very soluble and very deliquescent.

Nitrate, or rather supernitrate, of alumina crystallizes, though with difficulty, in thin, soft, pliable flakes. It is of an austere and acid taste, and reddens blue vegetable colours. It may be formed by dissolving in diluted nitric acid, with the assistance of heat, fresh precipitated alumina, well washed but not dried. It is deliquescent, and soluble in a very small portion of water. Alcohol dissolves its own weight. It is easily decomposed by heat.

Nitrate of zircone was first discovered by Klaproth, and has since been examined by Guyton-Morveau and Vauquelin. Its crystals are small, capillary, silky needles. Its taste is astringent. It is easily decomposed by fire, very soluble in water, and deliquescent. It may be prepared by dissolving zircone in strong nitric acid; but, like the preceding species, the acid is always in excess.

Nitrate of yttria may be prepared in a similar manner. Its taste is sweetish and astringent. It is scarcely to be obtained in crystals; and if it be evaporated by too strong a heat, the salt becomes soft like honey, and on cooling concretes into a stony mass.

Acid (Nitrous). It was formerly called *fuming nitrous acid*. It appears to form a distinct genus of salts, that may be termed *nitrites*. But these cannot be made by a direct union of their component parts, being obtainable only by exposing a nitrate to a high temperature, which expels a portion of its oxygen in the state of gas, and leaves the remainder in the state of a nitrite, if the heat be not urged so far, or continued so long, as to effect a complete decomposition of the salt. In this way the nitrites of potash and soda may be obtained, and perhaps those of barytes, strontian, lime, and magnesia. The nitrites are particularly characterized, by being decomposable by all the acids except the carbonic, even by the nitric acid itself, all of which expel from them nitrous acid. We are little acquainted with any one except that of potash, which attracts moisture from the air, changes blue vegetable colours to green, is somewhat acrid to the taste, and when powdered, emits a smell of nitric oxide.

* The acid itself is best obtained by exposing nitrate of lead to heat in a glass retort. Pure *nitrous* acid comes over in the form of an orange coloured liquid. It is so volatile, as to boil at the temperature of 82°. Its specific gravity is 1.450. When mixed with water it is decomposed, and nitrous gas is disengaged, occasioning effervescence. It is composed of one volume of oxygen united with two of nitrous gas. It therefore consists by weight of 1.75 nitrogen + 4 oxygen; by measure of 1½ oxygen + 1 nitrogen. The various coloured acids of nitre are not *nitrous* acids, but nitric acid impregnated with nitrous gas, the deutoxide of nitrogen, or azote. (See the preceding table of Sir H. Davy, concerning the coloured acid.)*

* **Acid (Nitric Oxygenized).** In our general remarks on acidity, we have described Mr. Thenard's newly discovered method of oxygenizing the liquid acids. The first that he examined was the combination of nitric acid and oxygen. When the peroxide of barium, prepared by saturating barytes with oxygen, is moistened, it falls to powder, without much increase of temperature. If in this state it be mixed with seven or eight times its weight of water, and dilute nitric acid be gradually poured upon it, it dissolves gradually by agitation, without the evolution of any gas. The solution is neutral, or has no action on turnsole or turmeric. When we add to this solution the requisite quantity of sulphuric acid, a copious precipitate of sulphate of barytes falls, and the filtered

liquor is merely water, holding in solution oxygenized nitric acid. This acid is liquid and colourless; it strongly reddens turnsole, and resembles in all its properties nitric acid.

When heated it immediately begins to discharge oxygen; but its decomposition is never complete unless it be kept boiling for some time. The only method which M. Thenard found successful for concentrating it, was to place it in a capsule, under the receiver of an air pump, along with another capsule full of lime, and to exhaust the receiver. By this means he obtained an acid sufficiently concentrated to give out 11 times its bulk of oxygen gas.

This acid combines very well with barytes, potash, soda, ammonia, and neutralizes them. When crystallization commences in the liquid, by even a spontaneous evaporation, these salts are instantly decomposed. The exhausted receiver also decomposes them. The oxygenized nitrates, when changed into common nitrates, do not change the state of their neutralization. Strong solution of potash poured into their solutions decomposes them.

Oxygenized nitric acid does not act on gold; but it dissolves all the metals which the common acid acts on, and when it is not too concentrated, it dissolves them without effervescence. Deutoxide, or peroxide of barium, contains just double the proportion of oxygen that its protoxide does. But M. Thenard says, that the barytes obtained from the nitrate by ignition contains always a little of the peroxide. When oxygenized nitric acid is poured upon oxide of silver, a strong effervescence takes place, owing to the disengagement of oxygen. One portion of the oxide of silver is dissolved, the other is reduced at first, and then dissolves likewise, provided the quantity of acid be sufficient. The solution being completed, if we add potash to it, by little and little, a new effervescence takes place, and a dark violet precipitate falls; at least this is always the colour of the first deposite. It is insoluble in ammonia, and according to all appearance, is a protoxide of silver.

As soon as we plunge a tube containing oxide of silver into a solution of oxygenized nitrate of potash, a violent effervescence takes place, the oxide is reduced, the silver precipitates, the whole oxygen of the oxygenized nitrate is disengaged at the same time with that of the oxide; and the solution, which contains merely common nitrate of potash, remains neutral, if it was so at first. But the most unaccountable phenomenon is the following: If silver, in a state of extreme division (fine filings), be put into the oxygenized nitrate, or oxygenized muriate of potash, the whole oxygen is immediately disengaged. The silver itself is not attacked, and the salt remains neutral as before. Iron, zinc, copper, bismuth, lead, and platinum, likewise possess this property of separating the oxygen of the oxygenized nitrate. Iron and zinc are oxidized, and at the same time occasion the evolution of oxygen. The other metals are not sensibly oxidized. They were all employed in the state of filings. Gold scarcely acts. The peroxides of manganese and of lead decompose the oxynitrates. A very small quantity of these oxides, in powder, is sufficient to drive off the whole oxygen from the saline solution. The effervescence is lively. The peroxide of manganese undergoes no alteration.

Though nitric acid itself has no action on the peroxides of lead and manganese, the oxygenized acid dissolves both of them with the greatest facility. The solution is accompanied by a great disengagement of oxygen gas. The effect of silver, he thinks, may probably be ascribed to voltaic electricity.

The remarks appended to our account of M. Thenard's oxygenized muriatic acid, are equally applicable to the nitric; but the phenomena are too curious to be omitted in a work of the present kind.*

* ACID (OLEIC). When potash and hog's lard are saponified, the margarate of the alkali separates in the form of a pearly looking solid, while the fluid fat remains in solution, combined with the potash. When the alkali is separated by tartaric acid, the oily principle of fat is obtained, which M. Chevreul purifies by saponifying it again and again, recovering it two or three times, by which means the whole of the margarine is separated. As this oil has the property of saturating bases and forming neutral compounds, he has called it oleic acid. In his sixth memoir, he gives the following table of results.

100 Oleic acid of human fat

Saturate	Barytes	Strontian	Lead
	26.00	19.41	82.48
100 Oleic acid of sheep fat			
	26.77	19.38	81.81
100 Oleic acid of ox fat			
	28.93	19.41	81.81
100 Oleic acid of goose fat			
	26.77	19.38	81.34
100 Oleic acid of hog fat			
	27.00	29.38	81.80

Oleic acid is an oily fluid without taste and smell. Its specific gravity is 0.914. It is generally soluble in its own weight of boiling alcohol, of the specific gravity of 0.7952; but some of the varieties are still more soluble. 100 of the oleic acid saturate 16.58 of potash, 10.11 of soda, 7.52 of magnesia, 14.83 of zinc, and 13.93 peroxide of copper. M. Chevreul's experiments have finally induced him to adopt the quantities of 100 acid to 27 barytes, as the most correct; whence calling barytes 9.75, we have the equivalent prime of oleic acid = 36.0.*

Acid (Oxalic). This acid, which abounds in wood sorrel, and which, combined with a small portion of potash, as it exists in that plant, has been sold under the name of *salt of lemons*, to be used as a substitute for the juice of that fruit, particularly for discharging ink spots and iron-moulds, was long supposed to be analogous in that of tartar. In the year 1776, however, Bergmann discovered, that a powerful acid might be extracted from sugar by means of the nitric; and a few years afterwards Scheele found this to be identical with the acid existing naturally in sorrel. Hence the acid began to be distinguished by the name of *saccharine*, but has since been known in the new nomenclature by that of oxalic.

Scheele extracted this acid from the salt of sorrel, or acidulous oxalate of potash, as it exists in the juice of that plant, by saturating it with ammonia, when it becomes a very soluble triple salt, and adding to the solution nitrate of barytes dissolved in water. Having well washed the oxalate of barytes, which is precipitated, he dissolved it in boiling water, and precipitated its base by sulphuric acid. To ascertain that no sulphuric acid remained in the supernatant liquor, he added a little of a boiling solution of oxalate of barytes till no precipitate took place, and then filtered the liquor, which contained nothing but pure oxalic acid, which he crystallised by evaporation and cooling.

It may be obtained, however, much more readily and economically from sugar in the following way: To six ounces of nitric acid in a stoppered retort, to which a large receiver is luted, add, by degrees, one ounce of lump sugar coarsely powdered. A gentle heat may be applied during the solution, and nitric oxide will be evolved in abundance. When the whole of the sugar is dissolved, distil off a part of the acid, till what remains in the retort has a sirupy consistence, and this will form regular crystals, amounting to 58 parts from 100 of sugar. These crystals must be dissolved in water, re-crystallized, and dried on blotting paper.

A variety of other substances afford the oxalic acid when treated by distillation with the nitric. Bergmann procured it from honey, gum arabic, alcohol, and the calculous concretions in the kidneys and bladders of animals. Scheele and Hermbstadt from sugar of milk. Scheele from a sweet matter contained in fat oils, and also from the uncrystallizable part of the juice of lemons. Hermbstadt from the acid of cherries, and the acid of tartar. Goetling from beech wood. Kohl from the residuum in the distillation of ardent spirits. Westrumb not only from the crystallized acids of currants, cherries, citrons, raspberries, but also from the saccharine matter of these fruits, and from the uncrystallizable parts of the acid juices. Hoffmann from the juice of the barberry; and Berthollet from silk, hair, tendons, wool; also from other animal substances, especially from the coagulum of blood, whites of eggs, and likewise from the amylaceous and glutinous parts of flour. M. Berthollet observes, that the quantity of the oxalic acid obtained by treating wool with nitric acid was very considerable, being above half the weight of the wool employed. He mentions a difference which he observed between animal and vegetable substances thus treated with nitric acid, namely, that the former yielded, beside ammonia, a large quantity of an oil which the nitric acid could not decompose; whereas the oily parts of vegetables were totally destroyed by the action of this acid: and he remarks, that in this instance the glutinous part of flour resembled animal substances, whereas the amylaceous part of the flour retained its vegetable properties. He further remarks, that the quantity of oxalic acid furnished by vegetable matters thus treated is proportionable to their nutritive quality, and particularly that, from cotton, he could not obtain any sensible quantity. Deyeux, having cut with scissars the hairs of the chick pea, found they gave out an acid liquor, which, on examination, proved to be an aqueous solution of pure oxalic acid. Proust and other chemists had before observed, that the shoes of persons walking through a field of chick pease were corroded.

Oxalic acid crystallizes in quadrilateral prisms, the sides of which are alternately broad and narrow, and summits diëdral; or, if crystallized rapidly, in small irregular needles. They are efflorescent in dry air, but attract a little humidity if it be damp; are soluble in one part of hot and two of cold water; and are decomposable by a red heat, leaving a small quantity of coaly residuum.—100 parts of alcohol take up near 56 at a boiling heat, but not above 40 cold. Their acidity is so great, that when dissolved in 3600 times their weight of water, the solution reddens litmus paper, and is perceptibly acid to the taste.

The oxalic acid is a good test for detecting lime, which it separates from all the other acids, unless they are present in excess. It has likewise a greater affinity for lime than for any other of the bases, and forms with it a pulverulent insoluble salt, not decomposable except by fire, and turning sirup of violets green.

* From the oxalate of lead, Berzelius infers its prime equivalent to be 4.552, and by igneous decomposition he finds it resolved into 66.534 oxygen, 33.222 carbon, and 0.244 hydrogen. The quantity of the latter, when reduced to primitive ratios, gives only, as Dr. Thomson admits, 1-12th of an atom of hydrogen, which makes this analysis of Berzelius and the Atomic theory incompatible. Since Berzelius published his analysis, oxalic acid has been made the subject of some ingenious remarks by Dobereiner, in the 16th vol. of Schweigger's Journal. We see that the carbon and oxygen are to each other in the simple ratio of 1 to 2; or referred to their prime equivalent, as 2 of carbon = 1.5, to 3 of oxygen = 3. This proportion is what would result from a prime of carbonic acid = $C + 2.O$, combined with one of carbonic oxide = $C + O$. C being carbon, and O oxygen. The sum of the above weights gives 4.5 for the prime equivalent of oxalic acid, disregarding hydrogen, which constitutes but 1-37th of the whole, and may possibly be referred to the imperfect desiccation of the oxalate of lead subjected to analysis. Oxalic acid acts as a violent poison when swallowed in the quantity of 2 or 3 drachms; and several fatal accidents have lately occurred in London, in consequence of its being improperly sold instead of Epsom salts. Its vulgar name of salts, under which the acid is bought for the purpose of whitening boot-tops, occasions these lamentable mistakes. But the powerfully acid taste of the latter substance, joined to its prismatic or needle-formed crystallization, are sufficient to distinguish it from every thing else. The immediate rejection from the stomach of this acid, by an emetic, aided by copious draughts of warm water containing bicarbonate of potash, or soda, chalk, or carbonate of magnesia, are the proper remedies.*

With barytes it forms an insoluble salt; but this salt will dissolve in water acidulated with oxalic acid, and afford angular crystals. If, however, we attempt to dissolve these crystals in boiling water, the excess of acid will unite with the water, and leave the oxalate, which will be precipitated.

The oxalate of strontian too is a nearly insoluble compound.

Oxalate of magnesia too is insoluble, unless the acid be in excess.

The oxalate of potash exists in two states, that of a neutral salt, and that of an acidule. The latter is generally obtained from the juice of the leaves of the *oxalis acetosella*, wood sorrel, or *rumex acetosa*, common sorrel. The expressed juice, being diluted with water, should be set by for a few days, till the feculent parts have subsided, and the supernatant fluid is become clear; or it may be clarified, when expressed, with the whites of eggs. It is then to be strained off, evaporated to a pellicle, and set in a cool place to crystallize. The first product of crystals being taken out, the liquor may be further evaporated, and crystallized; and the same process repeated till no more can be obtained. In this way Schlereth informs us about nine drachms of crystals may be obtained from two pounds of juice, which are generally afforded by ten pounds of wood sorrel. Savary, however, says, that ten parts of wood sorrel in full vegetation yield five parts of juice, which give little more than a two-hundredth of tolerably pure salt. He boiled down the juice, however, in the first instance, without clarifying it; and was obliged repeatedly to dissolve and re-crystallize the salt to obtain it white.

This salt is in small, white, needly, or lamellar crystals, not alterable in the air. It unites with barytes, magnesia, soda, ammonia, and most of the metallic oxides, into triple salts. Yet its solution precipitates the nitric solutions of mercury and silver in the state of insoluble oxalate of these metals, the nitric acid in this case combining with the potash. It attacks iron, lead, tin, zinc, and antimony.

This salt, besides its use in taking out ink spots, and as a test of lime, forms with sugar and water a pleasant cooling beverage; and according to Berthollet, it possesses considerable powers as an antiseptic.

The neutral oxalate of potash is very soluble, and assumes a gelatinous form, but may be brought to crystallize in hexaëdral prisms with diëdral summits, by adding more potash to the liquor than is sufficient to saturate the acid.

Oxalate of soda likewise exists in two different states, those of an acidulous and a neutral salt, which in their properties are analogous to those of potash.

The acidulous oxalate of ammonia is crystallizable, not very soluble, and capable, like the preceding acidules, of combining with other bases, so as to form triple salts. But if the acid be saturated with ammonia, we obtain a neutral oxalate, which on evaporation yields very fine crystals in tetraëdral prisms with diëdral summits, one of the planes of which cuts off three sides of the prism. This salt is decomposable by fire, which raises from it carbonate of ammonia, and leaves only some light traces of a coaly residuum. Lime, barytes, and strontian unite with its acid, and the ammonia flies off in the form of gas.

The oxalic acid readily dissolves alumina, and the solution gives on evaporation a yellowish transparent mass, sweet and a little astringent to the taste, deliquescent, and reddening tincture of litmus, but not sirup of violets This salt swells up in the fire, loses its acid, and leaves the alumina a little coloured.

* The composition of the different oxalates may be ascertained by considering the neutral salts as consisting of one prime of acid = 4.552 to 1 of base, and the binoxalate of potash of 2 of acid to 1 of base, as was first proved by Dr. Wollaston. But this eminent philosopher has further shown, that oxalic acid is capable of combining in four proportions with the oxides, whence result neutral oxalates, suboxalates, acidulous oxalates, and acid oxalates. The neutral contain twice as much acid as the suboxalates; one-half of the quantity of acid in the acidulous oxalates; and one-quarter of that in the acid oxalates.*

Acid (Perlate). This name was given by Bergmann to the acidulous phosphate of soda, Haupt having called the phosphate of soda *sal mirabile perlatum*.

Acid (Phosphoric.) The base of this acid, or the acid itself, abounds in the mineral, vegetable, and animal kingdoms. In the mineral kingdom it is found in combination with lead, in the green lead ore; with iron, in the bog ores which afford cold short iron; and more especially with calcareous earth in several kinds of stone. Whole mountains in the province of Estremadura in Spain are composed of this combination of phosphoric acid and lime. Mr. Bowles affirms, that the stone is whitish and tasteless, and affords a blue flame without smell when thrown upon burning coals. Mr. Proust describes it as a dense stone, not hard enough to strike fire with steel; and says that it is found in strata, which always lie horizontally upon quartz, and which are intersected with veins of quartz. When this stone is scattered upon burning coals, it does not decrepitate, but burns with a beautiful green light, which lasts a considerable time. It melts into a white enamel by the blow-pipe; is soluble with heat, and some effervescence in the nitric acid, and forms sulphate of lime with the sulphuric acid, while the phosphoric acid is set at liberty in the fluid.

The vegetable kingdom abounds with phosphorus, or its acid. It is principally found in plants that grow in marshy places, in turf, and several species of the white woods. Various seeds, potatoes, agaric, soot, and charcoal afford phosphoric acid,§ by abstracting the nitric acid from them, and lixiviating the residue. The lixivium contains the phosphoric acid, which may either be saturated with lime by the addition of lime-water, in which case it forms a solid compound; or it may be tried by examination of its leading properties by other chemical methods.

In the animal kingdom it is found in almost every part of the bodies of animals which are not considerably volatile. There is not, in all probability, any part of these organized beings which is free from it. It has been obtained from blood, flesh, both of land and water animals; from cheese; and it exists in large quantities in bones, combined with calcareous earth. Urine contains it, not only in a disengaged state, but also combined with ammonia, soda, and lime. It was by the evaporation, and distillation of this excrementitious fluid with charcoal that phosphorus was first made; the charcoal decomposing the disengaged acid and the ammoniacal salt. (See Phosphorus.) But it is more cheaply obtained by the process of Scheele, from bones, by the application of an acid to their earthy residue after calcination.

In this process the sulphuric acid appears to be the most convenient, because it forms a nearly insoluble compound with the lime of the bones. Bones of beef, mutton, or veal, being calcined to whiteness in an open fire, lose almost half of their weight. This must be pounded, and sifted, or the trouble may be spared by buying the powder that is sold to make cupels for the assayers, and is, in fact, the powder of burned bones ready sifted. To three pounds of the powder there may be added about two pounds of concentrated sulphuric acid. Four or five pounds of water must be afterward added to assist the action of the acid; and during the whole process the operator must remember to place himself and his vessels so that the fumes may be blown from him. The whole may then be left on a gentle sand bath for twelve hours or more, taking care to supply the loss of water which happens by evaporation. The next day a large quantity of water must be added, the whole strained through a sieve, and the residual matter, which is sulphate of lime, must be edulcorated by repeated affusions of hot water, till it passes tasteless. The waters contain phosphoric acid nearly free from lime, and by evaporation, first in glazed earthen, and then in glass vessels, or rather in vessels of platina or silver, for the hot acid acts upon glass, afford the acid in a concentrated state, which, by the force of a strong heat in a crucible, may be made to acquire the form of a transparent consistent glass, though indeed it is usually of a milky, opaque appearance.

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§ To this Prof. Bartholdi ascribes two accidents at the powder-mills at Essone, where spontaneous combustion appeared to have taken place in one instance in the charcoal store-room, in the other in the box into which the charcoal was sifted; as well as three successive explosions at the powder-mills of Vosges. This certainly merits the attention of gunpowder manufacturers.

For making phosphorus, it is not necessary to evaporate the water further than to bring it to the consistence of sirup; and the small portion of lime it contains is not an impediment worth the trouble of removing, as it affects the produce very little. But when the acid is required in a purer state, it is proper to add a quantity of carbonate of ammonia, which, by double elective attraction, precipitates the lime that was held in solution by the phosphoric acid. The fluid being then evaporated, affords a crystallized ammoniacal salt, which may be melted in a silver vessel, as the acid acts upon glass or earthen vessels. The ammonia is driven off by the heat, and the acid acquires the form of a compact glass as transparent as rock crystal, acid to the taste, soluble in water, and deliquescent in the air.

This acid is commonly pure, but nevertheless may contain a small quantity of soda, originally existing in the bones, and not capable of being taken away by this process, ingenious as it is. The only unequivocal method of obtaining a pure acid appears to consist in first converting it into phosphorus by distillation of the materials with charcoal, and then converting it again into acid by rapid combustion, at a high temperature, either in oxygen or atmospheric air, or some other equivalent process.

Phosphorus may also be converted into the acid state by treating it with nitric acid. In this operation, a tubulated retort with a ground stopper, must be half filled with nitric acid, and a gentle heat applied. A small piece of phosphorus being then introduced through the tube will be dissolved with effervescence, produced by the escape of a large quantity of nitric oxide. The addition of phosphorus must be continued until the last piece remains undissolved. The fire being then raised to drive over the remainder of the nitric acid, the phosphoric acid will be found in the retort, partly in the concrete and partly in the liquid form.

Sulphuric acid produces nearly the same effect as the nitric; a large quantity of sulphurous acid flying off. But as it requires a stronger heat to drive off the last portions of this acid, it is not so well adapted to the purpose. The liquid chlorine likewise acidifies it.

When phosphorus is burned by a strong heat, sufficient to cause it to flame rapidly, it is almost perfectly converted into dry acid, some of which is thrown up by the force of the combustion, and the rest remains upon the supporter.

This substance has also been acidified by the direct application of oxygen gas passed through hot water, in which the phosphorus was liquefied or fused.

The general characters of phosphoric acid are: 1. It is soluble in water in all proportions, producing a specific gravity, which increases as the quantity of acid is greater, but does not exceed 2.687, which is that of the glacial acid. 2. It produces heat when mixed with water, though not very considerable. 3. It has no smell when pure, and its taste is sour, but not corrosive. 4. When perfectly dry, it sublimes in close vessels; but loses this property by the addition of water; in which circumstance it greatly differs from the boracic acid, which is fixed when dry, but rises by the help of water. 5. When considerably diluted with water, and evaporated, the aqueous vapour carries up a small portion of the acid. 6. With charcoal or inflammable matter, in a strong heat, it loses its oxygen, and becomes converted into phosphorus.

Phosphoric acid is difficult of crystallizing.

Though the phosphoric acid is scarcely corrosive, yet, when concentrated, it acts upon oils, which it discolours, and at length blackens, producing heat, and a strong smell like that of ether and oil of turpentine; but does not form a true acid soap. It has most effect on essential oils, less on drying oils, and least of all on fat oils. Spirit of wine and phosphoric acid have a weak action on each other Some heat is excited by this mixture, and the product which comes over in distillation of the mixture is strongly acid, of a pungent arsenical smell, inflammable with smoke, miscible in all proportions with water, precipitating silver and mercury from their solutions, but not gold; and although not an ether, yet it seems to be an approximation to that kind of combination.

* From the syntheses of the phosphates of soda, barytes, and lead, Berzelius deduces the prime equivalent of phosphoric acid to be 4.5. But the experiments of Berzelius on the synthesis of the acid itself, show it to be a compound of about 100 phosphorus + 133 oxygen; or of 2 oxygen + 1.5 phosphorus = 3.5 for the prime equivalent of the acid. Lavoisier's synthesis gave 2 oxygen + 1.33 phosphorus. So did that of Sir H. Davy by rapid combustion in oxygen gas, as published in the Phil. Trans. for 1812. Dr. Thomson, in his account of the improvements in Physical Science, published in his Annals for January 1817, says, "It is quite clear from these analyses (of Berzelius) that the

equivalent number for phosphoric acid is 4.5." M. Dulong, in an elaborate paper published in the third volume of the Memoires d'Arcueil, gives as the result of diversified experiments, the proportions of 100 phosphorus to 123 oxygen; or of 2 oxygen + 1.627 phosphorus = 3.627 for the acid equivalent.

In the Annals of Philosophy for April 1816, page 305, Dr. Thomson gives the following statement: "From this result it follows that the acid is composed of

Phosphorus,	100
Oxygen,	123.46.

"To verify this result, the author (Dr. Thomson) had recourse to the phosphate of lead, which is a compound of 2 atoms phosphoric acid + 1 atom yellow oxide of lead." He gives three analyses of this salt; one by Dr. Wollaston; one by Professor Berzelius; and one by himself. These analyses are as follow:—

	Acid.	Base.
By Wollaston,	100 +	370.72
Berzelius,	100 +	380.56
Thomson,	100 +	398.49
Mean,	100 +	383.26.

This mean, which corresponds nearly with the analysis of Berzelius, is considered by him as exhibiting the true composition of phosphate of lead From this the weight of an atom of phosphoric acid is shown to be 3.649. But after a comparison of results by different methods, he says, "This gives us 1.634 for the weight of an atom of phosphorus; 2.634 for the weight of an atom of phosphorous acid; and 3.634 for the weight of an atom of phosphoric acid." Page 306.

In the subsequent January, when he gives an Account of Physical Science for the same year 1816, however, he says, "It is quite clear from these analyses," (of Berzelius, whom he there properly styles one of the most accurate chemists of the present day), "that the equivalent number for phosphoric acid is 4.5." And farther, in the fifth edition of his System of Chemistry, published in 1817, from an extremely large collection of experiments, he determines the equivalent of phosphorus to be 1.5; and that of phosphoric acid to be 4.5. Finally, in March 1820, without hinting in the least at his abandonment of the number 3.634, and adoption of 4.5, he merely says, "that a set of experiments he published some years ago seem to me to demonstrate the constitution of these two acids in a satisfactory manner." And he immediately fixes on 3.5 for phosphoric acid.

Amid all these perplexities, it is comfortable to resort to Sir H. Davy's clear and decisive paper, read before the Royal Society on the 9th April 1818. With his well known sagacity, he invented a new method of research, to elude the former sources of error. He burned the vapour of phosphorus as it issues from a small tube, contained in a retort filled with oxygen gas. By adopting this proces, he determined the composition of phosphoric acid to be 100 phosphorus + 134.5 oxygen; whence its equivalent comes out 3.500. Phosphorous acid he then shows to consist of 1 oxygen + 1.500 phosphorus = 2.500. We shall therefore fix on Sir H. Davy's number 3.500 for the prime equivalent of phosphoric acid.

We see, indeed, in the Annals of Philos. for 1816, in a paper on phosphuretted hydrogen by Dr. Thomson, that this chemist had determined the atom of phosphorus to be 1.5, and that of phosphoric acid 3.5, but he subsequently renounced them. It will be instructive to place his fluctuations of opinion in one view.

In the Annals for April 1816, the report of Dr. Thomson's paper, read at the Royal Society, on phosphoric acid and the phosphates, makes the acid equivalent 3.634; in the Annals for August 1816, the phosphuretted hydrogen experiments make it 3.5: the history of 1816 improvements, inserted in January 1817, gives us 4.5 as the equivalent, and an explicit renunciation of 3.5; the System of Chemistry in October 1817, confirms this number 4.5 by multiplied facts and reasonings; and, finally, after Sir H. Davy's experiments appeared in 1818, which demonstrated 3.500 to be the real number, Dr. Thomson resumes 3.5; and to show his claim to priority, refers simply to his former paper on phosphuretted hydrogen. From this example, beginners in the study of chemistry will learn the danger of dogmatizing hastily on experimental subjects.*

* Acid (Phosphorous) was discovered in 1812 by Sir H. Davy. When phosphorus and corrosive sublimate act on each other at an elevated temperature, a liquid called protochloride of phosphorus is formed. Water added to this, resolves it into muriatic and phosphorous acids. A moderate heat suffices to expel the former, and the latter remains, associated with water. It has a very sour taste, reddens vegetable blues, and neutralizes bases. When heated strongly in open vessels, it inflames. Phosphuretted hydrogen flies off, and phosphoric acid remains. Ten parts of it heated in close vessels give off 1½ of bihydroguret of phosphorus, and leave 8½ of phosphoric acid. Hence the liquid acid consists of 80.7 acid + 19.3 water. Its prime equivalent is 2.5.*

* Acid (Hypophosphorous), lately discovered by M. Dulong. Pour water on the phosphuret of barytes, and wait till all the phosphuretted hydrogen be disengag-

metals, but unites with their oxides, and forms salts for the most part insoluble; it likewise unites into triple salts with these oxides and alkalis; the oxygenated muriatic acid decomposes it.

The peculiar smell of the prussic acid could scarcely fail to suggest its affinity with the deleterious principle that rises in the distillation of the leaves of the lauro-cerasus, bitter kernels of fruits, and some other vegetable productions; and M. Schrader of Berlin has ascertained the fact, that these vegetable substances do contain a principle capable of forming a blue precipitate with iron; and that with lime they afford a test of the presence of iron, equal to the prussiate of that earth. Dr. Bucholz of Weimar, and Mr. Roloff of Magdeburg, confirm this fact. The prussic acid appears to come over in the distilled oil.

* Prussic acid and its combinations have been lately investigated by M. Gay-Lussac and Vauquelin in France, and Mr. Porrett in England, who have happily succeeded in removing in some measure the veil which continued to hang over this department of chemistry.

To a quantity of powdered prussian blue diffused in boiling water, let red oxide of mercury be added in successive portions till the colour is destroyed. Filter the liquid, and concentrate by evaporation till a pellicle appears. On cooling, crystals of prussiate or cyanide of mercury will be formed. Dry these, and put them into a tubulated glass retort, to the beak of which is adapted a horizontal tube about two feet long, and fully half an inch wide at its middle part. The first third part of the tube next the retort is filled with small pieces of white marble, the two other thirds with fused muriate of lime. To the end of this tube is adapted a small receiver, which should be artificially refrigerated. Pour on the crystals, muriatic acid, in rather less quantity than is sufficient to saturate the oxide of mercury, which formed them. Apply a very gentle heat to the retort. Prussic acid, named hydrocyanic by M. Gay-Lussac, will be evolved in vapour, and will condense in the tube. Whatever muriatic acid may pass over with it, will be abstracted by the marble, while the water will be absorbed by the muriate of lime. By means of a moderate heat applied to the tube, the prussic acid may be made to pass successively along; and after being left some time in contract with the muriate of lime, it may be finally driven into the receiver. As the carbonic acid evolved from marble by the muriatic is apt to carry off some of the prussic acid, care should be taken to conduct the heat so as to prevent the distillation of this mineral acid.

Prussic acid thus obtained has the following properties. It is a colourless liquid, possessing a strong odour; and the exhalation, if incautiously snuffed up the nostrils, may produce sickness or fainting. Its taste is cooling at first, then hot, asthenic in a high degree, and a true poison. Its specific gravity at 44½°, is 0.7058; at 64° it is 0.6969. It boils at 81½°, and congeals at about 3°. It then crystallizes regularly, and affects sometimes the fibrous form of nitrate of ammonia. The cold which it produces, when reduced into vapour, even at the temperature of 68°, is sufficient to congeal it. This phenomenon is easily produced by putting a small drop at the end of a slip of paper or a glass tube. Though repeatedly rectified on pounded marble, it retains the property of feebly reddening paper tinged blue with litmus. The red colour disappears as the acid evaporates.

The specific gravity of its vapour, experimentally compared to that of air, is 0.9476. By calculation from its constituents, its true specific gravity comes out 0.9360, which differs from the preceding number by only one-hundredth part. This small density of prussic acid, compared with its great volatility, furnishes a new proof that the density of vapours does not depend upon the boiling point of the liquids that furnish them, but upon their peculiar constitution.

M. Gay-Lussac analyzed this acid by introducing its vapour at the temperature of 86° into a jar, two-thirds filled with oxygen, over warm mercury. When the temperature of the mercury was reduced to that of the ambient air, a determinate volume of the gaseous mixture was taken and washed in a solution of potash, which abstracts the prussic acid, and leaves the oxygen. This gaseous mixture may after this inspection, be employed without any chance that the prussic acid will condense, provided the temperature be not too low; but during M. Gay-Lussac's experiments it was never under 71½°. A known volume was introduced into a Volta's eudiometer, with platina wires, and an electric spark was passed across the gaseous mixture. The combustion is lively, and of a bluish white colour. A white prussic vapour is seen, and a diminution of volume takes place, which is ascertained by measuring the residue in a graduated tube. This being washed with a solution of potash or barytes, suffers a new diminution from the absorption of the carbonic acid gas formed. Lastly, the gas, which the alkali has left, is analyzed over water by hydrogen, and it is ascertained to be a mixture of nitrogen and oxygen, because this last gas was employed in excess.

The following are the results, referred to prussic acid vapour.

Vapour,	100
Diminution after combustion,	78.5
Carbonic acid gas produced,	101.0
Nitrogen,	46.0
Hydrogen,	55.0

During the combustion a quantity of oxygen disappears, equal to about 1¼ of the vapour employed. The carbonic acid produced represents one volume; and the other fourth is supposed to be employed in forming water; for it is impossible to doubt that hydrogen enters into the composition of prussic acid. From the laws of chemical proportions, M. Gay-Lussac concludes that prussic acid vapour contains just as much carbon as will form its own bulk of carbonic acid, half a volume of nitrogen, and half a volume of hydrogen. This result is evident for the carbon; and though, instead of 50 of nitrogen and hydrogen, which ought to be the numbers according to the supposition, he obtained 46 for the first, and 55 for the second, he ascribes the discrepancy to a portion of the nitrogen having combined with the oxygen to form nitric acid.

The density of carbonic acid gas being, according to M. Gay-Lussac, 1.5196, and that of oxygen 1.1036, the density of the vapour of carbon is 1.5196 — 1.1036 = 0.4160. Hence 1 volume carbon, = 0.4160
Half a volume of hydrogen, = 0.0366
Half a volume of nitrogen, = 0.4845

Sum, = 0.9371

Thus, according to the analytical statement, the density of prussic vapour is 0.9371, and by direct experiment it was found to be 0.9476. It may therefore be inferred from this near coincidence, that prussic acid vapour contains one volume of the vapour of carbon, half a volume of nitrogen, and half a volume of hydrogen, condensed into one volume, and that no other substance enters into its composition.

M. Gay-Lussac confirmed the above determination, analyzing prussic acid by passing its vapour through an ignited porcelain tube containing a coil of fine iron wire, which facilitates the decomposition of this vapour, as does it with ammonia. No trace of oxygen could be found in prussic acid. And again, by transmitting the acid in vapour over ignited peroxide of copper in a porcelain tube, he came to the same conclusion with regard to its conconstituents. They are,—

One volume of the vapour of carbon,
Half a volume of hydrogen,
Half a volume of nitrogen,

condensed into one volume; or in weight,

Carbon,	44.39
Nitrogen,	51.71
Hydrogen,	3.90
	100.00

This acid, when compared with the other animal products, is distinguished by the great quantity of nitrogen it contains, by its small quantity of hydrogen, and especially by the absence of oxygen.

When this acid is kept in well-closed vessels, even though no air be present, it is sometimes decomposed in less than an hour. It has been occasionally kept 15 days without alteration; but it is seldom that it can be kept longer, without exhibiting signs of decomposition. It begins by assuming a reddish brown colour, which becomes deeper and deeper, and it gradually deposites a considerable carbonaceous matter, which gives a deep colour to both water and acids, and emits a strong smell of ammonia. If the bottle containing the prussic acid be not hermetically sealed, nothing remains but a dry charry mass, which gives no colour to water. Thus a prussiate of ammonia is formed at the expense of a part of the acid, and an azoturet of carbon. When potassium is heated in prussic acid vapour mixed with hydrogen or nitrogen, there is absorption without inflammation, and the metal is converted into a gray spongy substance, which melts, and assumes a yellow colour.

Supposing the quantity of potassium employed capable of disengaging from water a volume of hydrogen equal to 50 parts, we find after the action of the potassium,—

1. That the gaseous mixture has experienced a diminution of volume amounting to 50 parts: 2. On treating this mixture with potash, and analyzing the residue by oxygen, that 50 parts of hydrogen have been produced: 3. And consequently that the potassium has absorbed 100 parts of prussic vapour; for there is a diminution of 50 parts, which would obviously have been twice as great had not 50 parts of hydrogen been disengaged. The yellow matter is prussiate of potash; properly a prusside of potassium, analogous in its formation to the chloride and iodide, when muriatic and hydriodic gases are made to act on potassium.

The base of prussic acid thus divested of its acidifying hydrogen, should be called, agreeably to the same chemical analogy, prussine. M. Gay-Lussac styles it cyanogen, because it is the principle which generates blue [illegible] or literally, the blue-maker.

Like muriatic and hydriodic acids also, it contains half its volume of hydrogen.

The only difference is, that the former have in the present state of our knowledge simple radicals, chlorine and iodine, while that of the latter is a compound of one volume vapour of carbon, and half a volume of nitrogen. This radical forms true prussides with metals.

If the term cyanogen be objectionable as allying it to oxygen, instead of chlorine and iodine, the term hydrocyanic acid must be equally so, as implying that it contains water. Thus we say hydronitric, hydromuriatic, and hydrophosphoric, to denote the aqueous compounds of the nitric, muriatic, and phosphoric acids. As the singular merit of M. Gay-Lussac, however, has commanded a very general compliance among chemists with his nomenclature, we shall use the term prussic acid and hydrocyanic indifferently, as has long been done with the words nitrogen and azote.

The prusside or cyanide of potassium gives a very alkaline solution in water, even when a great excess of hydrocyanic vapour has been present at its formation. In this respect it differs from the chlorides and iodides of that metal, which are perfectly neutral. Knowing the composition of prussic acid, and that potassium separates from it as much hydrogen as from water, it is easy to find its proportional number or equivalent to oxygen. We must take such a quantity of prussic acid that its hydrogen may saturate 10 of oxygen. Thus we find the prime equivalent of this acid to be 33.846; and subtracting the weight of hydrogen, there remains 32.52 for the equivalent of cyanogen or prussine. But if we reduce the numbers representing the volumes to the prime equivalents adopted in this Dictionory, viz. 0.75 for carbon, 0.125 for hydrogen, and 1.75 for nitrogen, we shall have the relation of volumes slightly modified. Since the fundamental combining ratio of oxygen to hydrogen in bulk is $\frac{1}{2}$ to 1, we must multiply the prime equivalent by half the specific gravity of oxygen, and we obtain the following numbers:

$$1 \text{ volume car.} = 0.75 \times 0.5555 = 0.41663$$

$$\tfrac{1}{2} \text{ volume hyd.} = \frac{0.125 \times 0.5555}{2} = 0.03471$$

$$\tfrac{1}{2} \text{ volume nitr.} = \frac{1.75 \times 0.5555}{2} = 0.48610$$

$$\text{Sum} = 0.93744$$

Or, as is obvious by the above calculation, we may take 2 primes of carbon, 1 of hydrogen, and 1 of nitrogen, which directly added together will give the same results, since by so doing we merely take away the common multiplier 0.5555. Thus we have.

2 primes carbon, - - - -	1.500
1 prime hydrogen, - - -	0.125
1 prime nitrogen, - - -	1.750
	3.375

Which reduced to proportions per cent, give of

Carbon, - - - - - - -	44.444
Hydrogen, - - - - - -	3.704
Nitrogen, - - - - - -	51.852
	100.000

Barytes, potash, and soda combine with prussine, forming true prussides of these alkaline oxides; analogous to what are vulgarly called oxymuriates of lime, potash, and soda. The red oxide of mercury acts so powerfully on prussic acid vapour, when assisted by heat, that the compound which ought to result is destroyed by the heat disengaged. The same thing happens when a little of the concentrated acid is poured upon the oxide. A great elevation of temperature takes place, which would occasion a dangerous explosion if the experiment were made upon considerable quantities. When the acid is diluted, the oxide dissolves rapidly, with a considerable heat, and without the disengagement of any gas. The substance formerly called prussiate of mercury is generated, which when moist may, like the muriates, still retain that name; but when dry is a prusside of the metal.

When the cold oxide is placed in contact with the acid, dilated into a gaseous form by hydrogen, its vapour is absorbed in a few minutes. The hydrogen is unchanged. When a considerable quantity of vapour has thus been absorbed, the oxide adheres to the side of the tube, and on applying heat, water is obtained. The hydrogen of the acid has here united with the oxygen of the oxide to form the water, while their two radicals combine. Red oxide of mercury becomes an excellent reagent for detecting prussic acid.

By exposing the dry prusside of mercury to heat in a retort, the radical cyanogen or prussine is obtained. See PRUSSINE.

On subjecting hydrocyanic, or prussic acid, to the action of a battery of 20 pairs of plates, much hydrogen is disengaged at the negative pole; and cyanogen or prussine at the positive, which remains dissolved in the acid. This compound should be regarded as a hypoprussic or prussous acid. Since potash by heat separates the hydrogen of the prussic acid, we see that in exposing a mixture of potash and animal matters to a high temperature, a true prusside or cyanide of potash is obtained, formerly called the prussian or phlogisticated alkali. When cyanide of potassium is dissolved in water, hydrocyanate of potash is produced, which is decomposed by the acids without generating ammonia or carbonic acid; but when cyanide of potash dissolves in water no change takes place; and neither ammonia, carbonic acid, nor hydrocyanic vapour, is given out, unless an acid be added. These are the characters which distinguish a metallic cyanide from the cyanide of an oxide.

From the experiments of M. Magendie it appears, that the pure hydrocyanic acid is the most violent of all poisons. When a rod dipped into it is brought in contact with the tongue of an animal, death ensues before the rod can be withdrawn. If a bird be held a moment over the mouth of a phial containing this acid, it dies. In the Annales de Chimie for 1814 we find this notice: M. B. Professor of Chemistry, left by accident on a table a flask containing alcohol impregnated with prussic acid; the servant, enticed by the agreeable flavour of the liquid swallowed a small glass of it. In two minutes she dropped down dead, as if struck with apoplexy. The body was not examined.

"Scharinger, a professor at Vienna," says Orfila, "prepared six or seven months ago a pure and concentrated prussic acid; he spread a certain quantity of it on his naked arm, and died a little time thereafter."

Dr. Magendie has, however, ventured to introduce its employment into medicine. He found it beneficial against phthisis and chronic catarrhs. His formula is the following:—

Mix one part of the pure prussic or hydrocyanic acid of M. Gay-Lussac with 8½ of water by weight. To this mixture he gives the name of medicinal prussic acid.

Of this he takes 1 gros. or 59 gr. Troy.
Distilled water, 1 lb. or 7560 grs.
Pure sugar, 1½ oz. or 708¾ grs.

And mixing the ingredients well together, he administers a table spoonful every morning and evening. A well written report of the use of the prussic acid in certain diseases, by Dr. Magendie, was communicated by Dr. Granville to Mr. Brande, and is inserted in the fourth volume of the Journal of Science.

For the following ingenious and accurate process for preparing prussic acid for medicinal uses, I am indebted to Dr. Nimmo of Glasgow:

"Take of the ferroprussiate of potash 100 grains, of the protosulphate of iron 84½ grains; dissolve them separately in four ounces of water, and mingle them. After allowing the precipitate of the protoprussiate of iron to settle, pour off the clear part, and add water to wash the sulphate of potash completely away. To the protoprussiate of iron, mixed with four ounces of pure water, add 135 grains of the peroxide of mercury, and boil the whole till the oxide is dissolved. With the above proportions of peroxide of mercury, the protoprussiate of iron is completely decomposed. The vessel being kept warm, the oxide of iron will fall to the bottom, the clear part may be poured off to be filtered through paper, taking care to keep the funnel covered, so that crystals may not form in it by refrigeration. The residuum may be treated with more water, and thrown upon the filter, upon which warm water ought to be poured, until all the soluble part is washed away. By evaporation, and subsequent rest in a cool place, 145 grains of crystals of the prusside or cyanide of mercury will be procured in quadrangular prisms.

"The following process for eliminating the hydrocyanic acid I believe to be new. Take of the cyanide of mercury in fine powder one ounce, diffuse it in two ounces of water, and to it, by slow degrees, add a solution of hydrosulphuret of barytes, made by decomposing sulphate of barytes with charcoal in the common way. Of the sulphuret of barytes take an ounce, boil it with six ounces of water, and filter it as hot as possible. Add this in small portions to the cyanide of mercury, agitating the whole very well, and allowing sufficient time for the cyanide to dissolve, while the decomposition is going on between it and the hydrosulphuret as it is added. Continue the addition of the hydrosulphuret so long as a dark precipitate of sulphuret of mercury falls down, and even allowing a small excess. Let the whole be thrown upon a filter, and kept warm till the fluid drops through; add more water to wash the sulphuret of mercury, until eight ounces of fluid have passed through the filter, and it has become tasteless. To this fluid, which contains the prussiate of barytes, with a small excess of hydrosulphuret of barytes, add sulphuric acid, diluted with an equal weight of water, and allowed to become cold, so long as sulphate of barytes falls down. The excess of sulphuretted hydrogen will be removed by adding a sufficient portion of carbonate of lead, and agitating very well. The whole may now be put upon a filter, which must be closely covered; the fluid which passes is the hydrocyanic acid, of what is called the *medical* standard strength."

Dr. Nimmo finds, that cyanide of mercury is capable of dissolving the mercurial peroxide. Hence, the above proportions must be strictly observed, if we wish to obtain this powerful medicine of uniform strength. He conceives, therefore, that the ferroprussiate of potash should be taken for the basis of the calculation.

Scheele found that prussic acid occasioned precipitates with only the following three metallic solutions, nitrates of silver, and mercury, and carbonate of silver. The first is white, the second black, the third green becoming blue. In the Annals of Phil. for May 1820, Dr. Thomson gives an account of some metallic precipitates by a substance of a crystalline nature, which he obtained in the sublimation of prussian blue at a red heat, and which he reckons hydrocyanate of ammonia. But the nature of the substance is by no means demonstrated; and the precipitates differ so much from those of Scheele as to justify scepticism. Free prussic acid, for example, gives with nitrate of mercury a black precipitate; while Dr. Thomson's crystals give a white. Vauquelin found the crystals that sublime from prussian blue to be ammoniacal carbonate, and not hydrocyanate.

The hydrocyanates are all alkaline, even when a great excess of acid is employed in their formation; and they are decomposed by the weakest acids.

The hydrocyanate of ammonia crystallizes in cubes, in small prisms crossing each other, or in feathery crystals, like the leaves of a fern. Its volatility is such, that at the temperature of 71½°, it is capable of bearing a pressure of 17.72 inches of mercury; and at 97° its elasticity is equal to that of the atmosphere. Unfortunately this salt is charred and decomposed with extreme facility. Its great volatility prevented M. Gay-Lussac from determining the proportion of its constituents. What is known of the cyanides or prussides will be found under prussine, or their bases. M. Gay-Lussac considers prussian blue as a hydrated cyanide of iron, or a cyanide having water in combination; and M. Vauquelin, in a memoir lately read before the Academy of Sciences, regards prussian blue as a simple hydrocyanate of iron. He finds that water impregnated with cyanogen can dissolve iron without changing it into prussian blue, and without the disengagement of any hydrogen gas, while prussian blue was left in the undissolved portion. But hydrocyanic acid converts iron or its oxide into prussian blue without the help either of alkalis or acids. He conceives that cyanogen acts on iron and water as iodine does on water and a base; and that a CYANIC acid is formed which dissolves a part of the iron, but also and at the same time hydrocyanic acid, which changes another part of the iron into prussian blue. He farther lays it down as a general rule, that those metals which, like iron, decompose water at the ordinary temperature of the atmosphere, form hydrocyanates; and that those metals which do not possess this power, as silver and quicksilver, form only cyanides. Are we to regard the *cyanic* acid of M. Vauquelin as a compound of one prime of oxygen, and one of cyanogen, or in other words, one of oxygen, two of carbon, and and one of nitrogen?

According to M. Vauquelin, very complex changes take place when gaseous cyanogen is combined with water, which leave the nature of cyanic acid involved in great obscurity. The water is decomposed; part of its hydrogen combines with one part of the cyanogen, and forms hydrocyanic acid; another part unites with the nitrogen of the cyanogen, and forms ammonia; and the oxygen of the water forms carbonic acid, with one part of the carbon of the cyanogen. Hydrocyanate, carbonate, and cyanate of ammonia, are also found in the liquid; and there still remain some carbon and nitrogen, which produce a brown deposite. Four and a half parts of water absorb one of gaseous cyanogen, which communicates to it a sharp taste and smell, but no colour. The solution in the course of some days, however, becomes yellow, and afterwards brown, in consequence of the intestine changes related above.

Hydrocyanic acid is separated from potash by carbonic acid; but when oxide of iron is added to the potash, M. Gay-Lussac conceives that a triple compound, united by a much more energetic affinity, results, constituting what is usually called prussiate of potash, or prussiate of potash and iron. In illustration of this view, he prepared a hydrocyanate of potash and silver, which was quite neutral, and which crystallized in hexagonal plates. The solution of these crystals precipitates salts of iron and copper, white. Muriate of ammonia does not render it turpid; but muriatic acid, by disengaging hydrocyanic acid, precipitates chloride of silver. Sulphuretted hydrogen produces in it an analogous change. This compound, says M. Gay-Lussac, is evidently the triple hydrocyanate of potash and silver; and its formation ought to be analogous to that of the other triple hydrocyanates. "And as we cannot doubt," adds he, "that hydrocyanate of potash and silver is in reality, from the mode of its formation, a compound of cyanide of silver and hydrocyanate of potash, I conceive that the hydrocyanate of potash and iron is likewise a compound of neutral hydrocyanate of potash, and subcyanide of iron, which I believe to be combined with hydrocyanic acid in the white precipitate. We may obtain it perfectly neutral, and then it does not decompose alum; but the hydrocyanate of potash, which is always alkaline, produces in it a light and flocculent precipitate of alumina. To the same excess of alkali we must ascribe the ochry colour of the precipitates which hydrocyanate of potash forms with the persalts of iron. Thus the remarkable fact, which ought to fix the attention of chemists, and which appears to me to overturn the theory of Mr. Porrett, is, that hydrocyanate of potash cannot become neutral except when combined with the cyanides."*

* ACID (CHLOROCYANIC, or CHLOROPRUSSIC). M. Berthollet discovered, that when hydrocyanic acid is mixed with chlorine, it acquires new properties. Its odour is much increased. It no longer forms Prussian blue with solutions of iron, but a green precipitate, which becomes blue by the addition of sulphurous acid. Hydrocyanic acid thus altered had acquired the name of *oxyprussic*, because it was supposed to have acquired oxygen. M. Gay-Lussac subjected it to a minute examination, and found that it was a compound of equal volumes of chlorine and cyanogen, whence he proposed to distinguish it by the name of chlorocyanic acid. To prepare this compound he passed a current of chlorine into solution of hydrocyanic acid, till it destroyed the colour of sulphate of indigo; and by agitating the liquid with mercury, he deprived it of the excess of chlorine. By distillation, afterwards, in a moderate heat, an elastic fluid is disengaged, which possesses the properties formerly assigned to *oxyprussic* acid. This, however, is not pure chlorocyanic acid, but a mixture of it with carbonic acid, in proportions which vary so much, as to make it difficult to determine them.

When hydrocyanic acid is supersaturated with chlorine, and the excess of this last is removed by mercury, the liquid contains chlorocyanic and muriatic acids. Having put mercury into a glass jar till it was 3-4ths full, he filled it completely with that acid liquid, and inverted the jar in a vessel of mercury. On exhausting the receiver of an air pump containing this vessel, the mercury sunk in the jar, in consequence of the elastic fluid disengaged. By degrees the liquid itself was entirely expelled, and swam on the mercury on the outside. On admitting the air the liquid could not enter the tube, but only the mercury, and the whole elastic fluid condensed, except a small bubble. Hence it was concluded that chlorocyanic acid was not a permanent gas, and that, in order to remain gaseous under the pressure of the air, it must be mixed with another gaseous substance.

The mixture of chlorocyanic and carbonic acids, has the following properties. It is colourless. Its smell is very strong. A very small quantity of it irritates the pituitary membrane, and occasions tears. It reddens litmus, is not inflammable, and does not detonate when mixed with twice its bulk of oxygen or hydrogen. Its density, determined by calculation, is 2.111. Its aqueous solution does not precipitate nitrate of silver, nor barytes water. The alkalis absorb it rapidly, but an excess of them is necessary to destroy its odour. If we then add an acid, a strong effervescence of carbonic acid is produced, and the odour of chlorocyanic acid is no longer perceived. If we add an excess of lime to the acid solution, ammonia is disengaged in abundance. To obtain the green precipitate from solution of iron, we must begin by mixing chlorocyanic acid with that solution. We then add a little potash, and at last a little acid. If we add the alkali before the iron, we obtain no green precipitate.

M. Gay-Lussac deduces for the composition of chlorocyanic acid 1 volume of carbon + ½ a volume of azote + ½ a volume of chlorine; and when decomposed by the successive action of an alkali and an acid, it produces 1 volume of muriatic acid gas + 1 volume of carbonic acid + 1 volume of ammonia. The above three elements separately constituting two volumes, are condensed, by forming chlorocarbonic acid, into one volume. And since one volume of chlorine, and one volume of cyanogen, produce two volumes of chlorocyanic acid, the density of this last ought to be the half of the sum of the densities of its two constituents. Density of chlorine is 2.421, density of cyanogen 1.801, half sum = 2.111, as stated above: Or the proportions by weight will be 3.375 = a prime equivalent of cyanogen + 4.45 = a prime of chlorine, giving the equivalent of chlorocyanic acid = 7.825.

Chlorocyanic acid exhibits with potassium almost the same phenomena as cyanogen. The inflammation is equally slow, and the gas diminishes as much in volume.

The directions given by Dr. Thomson for forming chlorocyanic acid in the second volume of his System, 5th edition, p. 276, are apparently erroneous. He seems to have mistaken M. Gay-Lussac's ingenious plan for proving that this new acid is not naturally gaseous, for the process of obtaining the acid itself, as prescribed both by him and M. Thenard. The chlorocyanic and carbonic acids which come over in distillation, are to be condensed in water, or received over mercury. But the requisite process of distillation is not even hinted at by Dr. Thomson, whose chlorocyanic acid must be a mixture of chlorocyanic and muriatic acids.*

* ACID (FERROPRUSSIC). Into a solution of the amber-coloured crystals, usually called prussiate of potash, pour hydrosulphuret of barytes, as long as any precipitate falls. Throw the whole on a filter, and wash the precipitate with cold water. Dry it; and having dissolved 100

parts in cold water, add gradually 30 of concentrated sulphuric acid; agitate the mixture, and set it aside to repose. The supernatant liquid is ferroprussic acid, called by Mr. Porrett, who had the merit of discovering it, ferruretted chyazic acid.

It has a pale lemon yellow colour, but no smell. Heat and light decompose it. Hydrocyanic acid is then formed, and white ferroprussiate of iron, which soon becomes blue. Its affinity for the bases enables it to displace acetic acid, without heat, from the acetates, and to form ferroprussiates.

When a saline solution contains a base with which the ferroprussic acid forms an insoluble compound, then, agreeably to Berthollet's principle, it is capable of supplanting its acid. When ferroprussiate of soda is exposed to voltaic electricity, the acid is evolved at the positive pole, with its constituent iron. Mr. Porrett considers this acid "as a compound of

4 atoms carbon = 30.00
1 atom azote = 17.50
1 atom iron = 17 50
1 atom hydrogen = 1.25
66.25"

This sum represents the weight of its prime equivalent. Ferroprussiate of potash, and of barytes, will each, therefore, according to him, consist, of an atom of acid + an atom of base + two atoms of water.

Dr. Thomson says, in his System, "From the analysis of Mr. Porrett it appears, that this acid is composed of

Cyanogen,	8.904
Iron,	3.500

"This approaches to three atoms of cyanogen and one atom of iron, If we suppose this to be the real constitution of the acid, its constituents will be

Cyanogen,	9.75
Iron,	3.50

"But such a composition is quite irreconcileable to the equivalent number for ferrocyanic acid, derived from the analysis of the ferrocyanate of barytes. This salt, according to the experiments of Mr. Porrett, is composed of

Ferrocyanic acid,	34.31	6.813
Barytes,	49.10	9.750
Water,	16.59	
	100.00	

"We see that by this analysis the equivalent number for ferrocyanic acid is 6.813. Now this agrees very nearly with the supposition that the acid is a compound of one atom cyanogen + one atom iron. For the weights of an atom of these bodies are as follows:

Cyanogen,	3.25
Iron,	3.5

"The difference between 6.75 and 6.813 does not exceed one per cent. I am disposed, therefore, to consider this as the true constitution of ferrocyanic acid."

It is a real misfortune to chemical students, when so elaborate a systematist as Dr. Thomson so readily scatters around him precipitate and dogmatical judgments, on discussions of such importance and delicacy as the present. There were no reasonable grounds whatever for peremptorily deciding, as he did, that the ferruretted chyazic acid of Mr. Porrett was a simple cyanide of iron, or a compound of cyanogen and iron. The mere similarity of two numbers, viz. the sum of the atoms of cyanogen and iron, and the equivalent of Mr. Porrett's acid, were apparently the chief, and surely very frivolous motives, for that erroneous determination.

Mr Porrett expresses himself thus, in the Ann. of Phil. for September 1818. "It is a great satisfaction to me to find that Dr. Thomson has abandoned the opinion which he entertained, that the ferruretted chyazic acid contained no hydrogen, and was a compound of cyanogen and iron only; an opinion which induced him to name it, in his System of Chemistry, the ferrocyanic acid and its salts ferrocyanates. I was perfectly convinced, from many circumstances that occurred during my first experiments, that this opinion was erroneous, and should have combated it when it appeared in his System, had I been fond of controversy, or been able to find time for carrying on such a course of experiments, as would perhaps have been requisite to produce conviction in others. As it was, I contented myself with expressing to my chemical friends, my dissent from Dr. Thomson's opinion on this subject; and I can venture to assure him, that whenever he makes experiments with the sulphuretted chyazic acid, he will be convinced that it also contains hydrogen, and that the names sulphocyanic, and sulphocyanates, are quite inappropriate; equally so are the names proposed by Dr. Henry of ferroprussic, and sulphuretted prussic acids, as these names imply, that the prussic acid is contained in these compounds, instead of being merely the result of a new play of affinities when they are decomposed."

How little room there is for arbitrary decrees on every thing regarding the prussic combinations, we may readily judge, when we consider that M. Gay-Lussac, and M. Vauquelin, two of the first chemists of the age, have been led, after a series of admirable researches, to form views totally inconsistent with those resulting from Mr. Porrett's very ingenious experiments. On the relations of prussic acid and iron, the following observations by M. Vauquelin are important. Hydrocyanic acid diluted with water, when placed in contact with iron in a glass vessel standing over mercury, quickly produces prussian blue, while, at the same time, hydrogen gas is given out. The greatest part of the prussian blue formed in that operation, remains in solution in the liquid. It appears only when the liquid comes in contact with the air. This shows us that prussian blue, at a minimum of oxidizement, is soluble in hydrocyanic acid. Dry hydrocyanic acid, placed in contact with iron filings, undergoes no change in its colour nor smell; but the iron, which becomes agglutinated together at the bottom of the vessel, assumes a brown colour. After some days, the hydrocyanic acid being separated from the iron, and put in a small capsule under a glass jar, evaporated without leaving any residue. Therefore it had dissolved no iron. Hydrocyanic acid dissolved in water, placed in contact with hydrate of iron, obtained by means of potash, and washed with boiling water, furnished prussian blue immediately without the addition of any acid. Scheele has made mention of this fact. When hydrocyanic acid is in excess on the oxide of iron, the liquor which floats over the prussian blue assumes, after some time, a beautiful *purple* colour. The liquor, when evaporated, leaves upon the edge of the dish circles of blue, and others of a purple colour, and likewise crystals of this last colour. When water is poured upon these substances, the purple-coloured body alone dissolves, and gives the liquid a fine purple colour. The substance which remains undissolved is prussian blue, which has been held in solution in the hydrocyanic acid. Some drops of chlorine let fall into this liquid change it to blue, and a greater quantity destroys its colour entirely. It is remarkable that potash poured into the liquid thus deprived of its colour, occasions no precipitate whatever.

Chemists will not fail to remark, from these experiments, that hydrocyanic acid does not form prussian blue directly with iron; but that, on the addition of water, (circumstances remaining the same) prussian blue is produced. They will remark, likewise, that cyanogen united to water dissolves iron. This is confirmed by the inky taste which it acquires, by the disappearance of its colour, and by the residue which it leaves when evaporated; yet prussian blue is not formed. These first experiments seem already to show that prussian blue is a hydrocyanate, and not a cyanide.

The ammonia, and hydrocyanic acid, disengaged during the whole duration of the combustion of prussian blue, give a new support to the opinion, that this substance is a hydrocyanate of iron; and likewise the results which are furnished by the decomposition of prussian blue by heat in a retort, show clearly that it contains both oxygen and hydrogen, which are most abundant towards the end, long after any particles of adhering water must have been dissipated.

We shall conclude this subject with a comparison of Dr. Thomson's and Mr. Porrett's latest results. In the Annals of Phil. for August 1818, we have a paper by Dr. Thomson, detailing numerous experiments which he had performed to ascertain the constitution of prussiate of potash and iron. "From this analysis," says he, "it follows that the acid in the triple salt (not reckoning the iron) is composed of

Carbon,	0.6579	42.51
Azote.	0.7175	46.37
Hydrogen,	0.1722	11.12
	1.5476	100.00

"From the preceding analysis, we see, that the triple prussiate of potash is composed as follows:

Acid	Iron,	15.	45.90
	Gaseous matter,	30.9	
Potash,	- - -		41.64
Water,	- - -		13.00
			100.54

"We see, from the preceding analysis, that one-third part of the acid consists of iron, while two-thirds of its weight consists of carbon, azote, and hydrogen. The smallest number of atoms, which agrees nearly with the preceding proportions of the ingredients, is the following:

2 atoms carbon	= 1.50	41.379
1 atom azote	= 1.75	48.277
3 atoms hydrogen	= 0.375	10.344
	3.625	100.000"

Mr. Porrett, besides his communications to the Royal Society in 1814 and 1815, which Dr. Thomson justly describes "as very ingenious and important experiments, and conclusions respecting this acid," published two or three papers in the Annals of Philosophy, one of them in September 1818, already quoted, and another in October 1819. The latter presents us with experiments of the same nature as Dr. Thomson's, from which the following inferences are drawn.

"Collecting now from the preceding experiments the proportions of all the constituents of 100 gr. of ferrochyazate of potash, they appear as follows:

Potash, - -		41.68 gr.
Ferrochyazic acid	Iron,	12.60
	Carbon	22.64
	Azote,	13.32
	Hydrogen,	0.80
Water, - - -		13.00
		104.04

Being a surplus of four grains, arising from the unavoidable inaccuracies in determining experimentally, on small portions of the salt, the proportions of so many constituents.

" These inaccuracies are easily removed by the application of the atomic theory; for, by taking as our guide the weights of the atoms of each of the elements, we obtain the following numbers:

1 atom potash, -		60.	40.34
1 atom ferrochyazic acid = 66.25	½ atom iron,	17.5	11.76
	4 do. carbon,	30.0	20.17
	1 do. azote,	17.5	11.76
	1 do. hydrogen	1.250	0.84
2 atoms water, - -		22.50	15.13
1 at. ferrochyazate of potash,		148.75	100.00

Which doubtless gives the true proportions of the several elements of this salt."

" We are now entitled to consider the atom of ferrochyazic acid as composed of

4 atoms of carbon	= 30.00	45.3
1 atom of azote	= 17.5	26.4
1 atom of hydrogen	= 1.25	1.89
1 atom of iron	= 17.5	26.4
	66.25	99.99"

The discordances of these two sets of results, are such as to destroy all confidence in them. Thus, Dr. Thomson, finds 15 per cent of iron; and Mr. Porett's corrected quantity of that metal, per cent, is only 11¾, a difference quite absurd in the present state of chemical analysis. Here follows a tabular comparison, of the acid constituents, exclusive of the iron:

	Dr. Thomson.	Mr. Porrett.
Carbon,	42.51	61.54
Azote,	46.37	35.90
Hydrogen,	11.12	2.56
	100.00	100.00

It has been supposed that Mr. Porrett's new acid is nothing but a hydrocyanate or prussiate of iron, which, from the mutability of its constituents, is easily decomposed by heat and light; and that the only permanent compound which that acid forms is in triple salts. This is the old opinion, and also the present opinion, of several eminent chemists. These compounds we shall call ferroprussiates. M. Vauquelin and M. Thenard style them ferruginous prussiates.

Ferroprussiate of potash. Into an egg-shapped iron pot, brought to moderate ignition, project a mixture of good pearl-ash and dry animal matters, of which hoofs and horns are best, it the proportion of two parts of the former to five of the latter. Stir them well with a flat iron paddle. The mixture, as it calcines, will gradually assume a pasty form, during which transition it must be tossed about with much manual labour and dexterity. When the conversion into a chemical compound is seen to be completed by the cessation of the fetid animal vapours, remove the pasty mass with an iron ladle.

If this be thrown, while hot, into water, some of the prussic acid will be converted into ammonia, and of course the usual product diminished. Allow it to cool, dissolve it in water, clarify the solution by filtration or subsidence, evaporate, and, on cooling, yellow crystals of the ferroprussiate of potash will form. Separate these, redissolve them in hot water, and by allowing the solution to cool very slowly, larger and very regular crystals may be had. This salt is now manufactured in several parts of Great Britain, on the large scale; and therefore the experimental chemist need not incur the trouble and nuisance of its preparation. Nothing can exceed in beauty, purity, and perfection, the crystals of it prepared at Campsie, by Messrs Mackintosh and Wilson.

An extemporaneous ferroprussiate of potash may at any time be made, by acting on prussian blue, with pure carbonate of potash, prepared from the ignited bicarbonate or bitartrate. The blue should be previously digested, at a moderate heat, for an hour or two in its own weight of sulphuric acid diluted with five times its weight of water; then filtered, and thoroughly edulcorated by hot water, from the sulphuric acid. Of this purified prussian blue, add successive portions to the alkaline solution, as long as its colour is destroyed, or while it continues to change from blue to brown. Filter the liquid, saturate the slight alkaline excess with acetic acid, concentrate by evaporation, and allow it slowly to cool. Quadrangular bevelled crystals of the ferroprussiate of potash will form.

This salt is transparent, and of a beautiful lemon or topaz yellow. Its specific gravity is 1.830. It has a saline, cooling, but not unpleasant taste. In large crystals it possesses a certain kind of toughness, and, in thin scales, of elasticity. The inclination of the bevelled side to the plane of the crystal is about 135°. It loses about 13 per cent of water, when moderately heated; and then appears of a white colour, as happens to the green copperas;

but it does not melt like this salt. The crystals retain their figure till the heat verges on ignition. At a red heat it blackens, but, from the mode of its formation, we see that even that temperature is compatible with the existence of the acid, provided it be not too long continued. Water at 60° dissolves nearly one-third of its weight of the crystals; and at the boiling point, almost its own weight. It is not soluble in alcohol; and hence, chemical compilers, with needless scrupulosity have assigned to that liquid the hereditary sinecure of screening the salt from the imaginary danger of atmospherical action. It is not altered by the air. Exposed in a retort to a strong red heat, it yields prussic acid, ammonia, carbonic acid, and a coaly residue consisting of charcoal, metallic iron, and potash. When dilute sulphuric or muriatic acid is boiled on it, prussic acid is evolved, and a very abundant white precipitate of protoprussiate of iron and potash falls, which afterwards, treated with liquid chlorine, yields a prussian blue, equivalent to fully one-third of the salt employed. Neither sulphuretted hydrogen, the hydrosulphurets, nor infusion of galls, produce any change on this salt. Red oxide of mercury acts powerfully on its solution at a moderate heat. Prussiate of mercury is formed, which remains in solution; while peroxide of iron and metallic mercury precipitate. Thus we see that a portion of the mercurial oxide is reduced, to carry the iron to the maximum of oxidizement.

The solution of ferroprussiate of potash is not affected by alkalis; but it is decomposed by almost all the salts of the permanent metals. The following table presents a view of the colours of the metallic precipitates thus obtained.

Solutions of	Give a
Manganese,	White precipitate.
Protoxide of iron,	Copious white.
Deutoxide of iron,	Copious clear blue.
Tritoxide of iron,	Copious dark blue.
Tin,	White.
Zinc,	White.
Antimony,	White.
Uranium,	Blood coloured.
Cerium,	White.
Cobalt,	Grass green.
Titanium,	Green.
Bismuth,	White.
Protoxide of copper,	White.
Deutoxide of copper,	Crimson brown.
Nickel,	Apple green.
Lead,	White.
Deutoxide of mercury,	White.
Silver,	White, passing to blue, in the air.
Palladium,	Olive.
Rhodium, Platinum, and Gold,	None.

If some of these precipitates, for example those of manganese or copper, be digested in a solution of potash, we obtain a ferroprussiate of potash and iron exactly similar to what is formed by the action of the alkaline solution on prussian blue. Those precipitates, therefore, contain a quantity of iron. I think this fact is very favourable to the theory of Mr. Porrett; and scarcely explicable on any other supposition. This salt is composed of the following constituents, by the latest analyses.

	Mr. Porrett.	Dr. Thomson.
Potash,	40.34	41.64
Ferrochyazic acid,	44.53	45.90
Water,	15.13	13.00
	100.00	100.54

The small excess in the latter sum, Dr. Thomson thinks, may be equally divided among all the ingredients. We shall then have for his analysis:

Potash,	41.41
Acid,	45.67
Water,	12.92
	100.00

We have seen the enormous discrepancies with regard to the estimates of the *ultimate* acid constituents by these two experimentalists; and if we consider the directness and simplicity of the methods by which the *primary* constituents of the salt may be ascertained, the above differences also seem too great. By a well regulated desiccation, the water of crystallization may be pretty nearly determined; and the concurring results of *experiment* give for its quantity 13 per cent. Now the action of nitric acid properly conjoined with that of heat, should decompose and dissipate the gaseous part of the acid, and convert the iron into an insoluble peroxide; the weight of potash may then be exactly determined, first by saturation with acid, and secondly, by the weight of resulting salt. In fact had Mr. Porrett adhered to his experimental numbers, and not modified them by his atomical notions, we should have had the following results, which are probably correct.

Potash,	41.68
Water,	13.00
Ferrochyazic acid,	45.32
	100.00

And from this real analysis, we deduce directly from the proportion of potash = 41.68, the apparent prime equivalent of this neutral salt to be = 14.29; or rather its double, 28.58.

If we make it 28.275, then we would have the following hypothetical arrangement of proportions,

2 primes of potash,	=	11.900	42.04
2 do. of ferrochyazic acid,	=	13.000	45.96
3 do. of water,	=	3.375	12.00
		28.275	100.00

We have treated the subject of the ferroprussiate of potash at considerable detail, since it is one of the most valuable re-agents, which the chemist possesses, in metallic analysis.

Ferroprussiate of soda may be prepared from prussian blue, and pure soda, by a similar process to that prescribed for the preceding salt. It crystallizes in four-sided prisms, terminated by dihedral summits. They are yellow, transparent, have a bitter taste, and effloresce, losing in a warm atmosphere 37½ per cent. At 55° they are soluble in 4½ parts of water, and in a much less quantity of boiling water. As the solution cools, crystals separate. Their specific gravity is 1.458. They are said by Dr. John to be soluble in alcohol.

Ferroprussiate of lime may be easily formed from prussian blue and lime-water. Its solution yields crystalline grains by evaporation.

Ferroprussiate of barytes may be formed in the same way as the preceding species; or much more elegantly by Mr. Porrett's process, described already in treating of the ferroprussic acid. Its crystals are rhomboidal prisms, of a yellow colour, and soluble in 2000 parts of cold water, and 100 of boiling water. By Mr. Porrett's second account of this salt, it is composed of

	Exper't.	Theory.		
Acid,	41.5	41.49	1 atom	84.84
Barytes,	47.5	47.44	1 atom	97.00
Water,	11.0	11.07	2 atoms	22.64
	100.0	100.00		204.48

These results were given in the Annals of Philosophy for September 1818. In Dr. Thomson's System, published in October 1817, we have the following statement:—"Mr. Porrett has analyzed this salt with much precision. According to his experiments, it is composed of

Ferrocyanic acid,	34.31
Barytes,	49.10
Water,	16.59
	100.00"

In the Annals for October 1819, Mr. Porrett gives as its true proportions,

1 atom ferrochyazic acid,	66.25	35.66
1 atom barytes,	97.	52.22
2 atoms water,	22.5	12.12
	185.75	100.00

The discrepancies are singular, with a substance so unalterable and so easily ascertained as barytes; for Dr. Thomson's quotation gives of this substance 49.1 per cent.; the second account makes it 47.5; and the last 52.22. The quantity of barytes may be determined absolutely, without being deduced from, or entangled with, the estimate of water or acid.

Ferroprussiate of strontian and magnesia have also been made.

Ferroprussiate of iron. With the protoxide of iron and this acid we have a white powder, which, on exposure to air, becomes blue, passing into *deutoferroprussiate of iron*, or prussian blue. We have already described the method of making the ferroprussiate of potash, which is the first step in the manufacture of this beautiful pigment. This is usually made by mixing together one part of the ferroprussiate of potash, one part of copperas, and four parts or more of alum, each previously dissolved in water. Prussian blue, consisting of the deutoferroprussiate of iron, mixed with more or less alumina, precipitates. It is afterwards dried on chalk stones, in a stove.

Pure prussian blue is a mass of an extremely deep blue colour, insipid, inodorous, and considerably denser than water. Neither water nor alcohol has any action on it. Boiling solutions of potash, soda, lime, barytes, and strontites decompose it; forming on one hand soluble ferroprussiates with these bases, and on the other a residue of brown deutoxide of iron, and a yellowish brown subferroprussiate of iron. This last, by means of sulphuric, nitric, or muriatic acid, is brought back to the state of a ferroprussiate, by abstracting the excess of iron oxide. Aqueous chlorine changes the blue to a green in a few minutes, if the blue be recently precipitated. Aqueous sulphuretted hydrogen, reduces the blue ferroprussiate to the white protoferroprussiate.

Its igneous decomposition in a retort has lately been executed by M. Vauquelin with minute attention. He regards it as a hydrocyanate or mere prussiate of iron; but the changes he describes are very complex, nor do they invalidate Mr. Porrett's opinion, that it is a combination of red oxide of iron, with a ferruretted acid. The general results of M. Vauquelin's analysis, were hydrocyanic acid, hydrocyanate of ammonia, an oil soluble in potash, crystalline needles, which contained no hydrocyanic acid, but were merely carbonate of ammonia; and finally, a ferreous residue slightly attracted by the magnet, and containing a little undecomposed prussian blue. If we are to regard prussian blue as a deutoferroprussiate of iron, then by Mr. Porrett's latest considerations, it would be composed of

1 atom acid,	= 6.625	35.1
1 atom red oxide,	= 10.000	53.0
2 atoms water,	= 2.250	11.9
	18.875	100.0

Dr. Thomson, after reporting it from Mr. Porrett to consist of

Acid,	53.38	6.75
Peroxide of iron,	34.23	4.328
Water,	12.39	
	100.00	

thinks it likely that the true composition is,

Ferrocyanic acid,	6.75
Peroxide of iron,	5.00

Proust, in the Annales de Chimie, vol. lx. states, that 100 parts of prussian blue, without alum, yield 0.55 of red oxide of iron by combustion; and by nitric acid, 0.54. 100 of prussiate of potash and iron, he further says, afford, after digestion with sulphuric or nitric acid, 35 parts of prussian blue. If we compare with this, Mr. Porrett's earliest estimate of 34.23 per cent of ferreous peroxide, besides the third of the weight of the acid, = 17.79, which being metallic iron, is equivalent to 25.4 of peroxide, we shall have the sum 59.63, as the quantity of peroxide in 100 of prussian blue, calling the atom of iron 3.5, and of peroxide 5.0. Or if we take Dr. Thomson's correction, we have the following numbers, supposing it to consist of

1	atom acid,	6.75	48.2
1	peroxide,	5.00	35.7
2	water,	2.25	16.1
		14.00	100.0

or perhaps

1	atom acid,	6.75	52.3
1	peroxide,	5.00	39.0
1	water,	1.125	8.7
		12.875	100.0

To the 35.7 of peroxide base in the first, if we add 23 for the equivalent of peroxide in its acid, we have 58.7 for the whole peroxide in 100 gr.; and to the 39 of peroxide in the second, if we add 25 for the equivalent peroxide in the acid, we have the sum of 64; both, quantities considerably greater than Mr. Proust's.[*]

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[*] Sulphuroprussic Acid; the sulphuretted chyazic acid of Mr. Porrett.

Dissolve in water one part of sulphuret of potash, and boil it for a considerable time with three or four parts of powdered prussian blue added at intervals. Sulphuret of iron is formed, and a colourless liquid containing the new acid combined with potash, mixed with hyposulphite and sulphate of potash. Render this liquid sensibly sour, by the addition of sulphuric acid. Continue the boiling for a little, and when it cools, add a little peroxide of manganese in fine powder, which will give the liquid a fine crimson colour. To the filtered liquid add a solution containing persulphate of copper, and protosulphate of iron, in the proportion of two of the former salt to three of the latter, until the crimson colour disappears. Sulphuroprussiate of copper falls. Boil this with a solution of potash, which will separate the copper. Distil the liquid mixed with sulphuric acid in a glass retort, and the peculiar acid will come over. By saturation with carbonate of barytes, and then throwing down this by the equivalent quantity of sulphuric acid, the sulphuroprussic acid is obtained pure.

It is a transparent and colourless liquid, possessing a strong odour, somewhat resembling acetic acid. Its specific gravity is only 1.022. It dissolves a little sulphur at a boiling heat. It then blackens nitrate of silver; but the pure acid throws down the silver white. By repeated distillations, sulphur is separated and the acid is decomposed. Mr. Porrett, in the Annals of Phil. for May 1819, states the composition of this acid, as it exists in the sulphuretted chyazate of copper, to be

2	atoms sulphur,	= 4.000
2	carbon,	= 1.508
1	azote,	= 1.754
1	hydrogen,	= 0.132
		7.394

This is evidently an atom of the hydrocyanic acid of M. Gay-Lussac, combined with 2 of sulphur. If to the above we add 9. for an atom of protoxide of copper, we have 16.394 for the prime equivalent of the metallic salt. When cyanogen and sulphuretted hydrogen were mixed together by M. Gay Lussac in his researches on the prussic principle, he found them to condense into yellow acicular crystals. Mr. Porrett has since remarked, that these crystals are not formed when the two gases are quite dry, but that they are quickly produced if a drop of water is passed up into the mixture. He does not think their solution in water corresponds to liquid sulphuretted chyazic acid; it does not change the colour of litmus; it has no effect on solutions of iron; it contains neither prussic nor sulphuretted chyazic acid, yet this acid is formed in it when it is mixed first with an alkali and then with an acid. The same treatment does not form any prussic acid.

The facility with which the atomic hypothesis may be twisted to any theoretical perversion, is well exemplified in the following passage:—"The weight of an atom of hydrocyanic acid is 3.375, and that of an atom of sulphur 2. But 6.328" (Mr. Porrett's first proportion of sulphur) "not being a multiple of two, this statement does not accord well with the atomic theory. It agrees much better with that theory, if we suppose the acid to be a compound of sulphur and cyanogen. Its constitution will then be,

Sulphur,	1.20	100	6.09
Cyanogen,	0.64	53.3	3.25

Thus we see that it is a compound of 1 atom of cyanogen and 3 atoms of sulphur." Thomson's System, Vol. ii. p. 292.

This procedure looks more like legerdemain than philosophical research. Had Dr. Thomson contented himself with saying that the statement of Mr. Porrett did not accord with the atomic theory, he would have said right; and there he should have left the matter, or have instituted *experiments* to settle the point. But to create a new genus of compounds, sulphur and cyanogen, and erect it into a new acid, on such a frivolous conceit, throws an air of ridicule on the science. Nay further, the Doctor describing M. Gay-Lussac's crystalline compound of sulphuretted hydrogen and cyanogen, says, that " as far as its description goes, this substance agrees exactly with the sulphuretted chyazic acid of Mr. Porrett. If we abstract the hydrogen of the sulphuretted hydrogen, which probably did not enter into the composition of the compound, it will be a compound of 1 atom cyanogen, and 1½ atom sulphur, or in whole numbers of 2 atoms cyanogen and 3 atoms sulphur. So that it will contain just half the quantity of sulphur which Mr. Porrett found." M. Gay-Lussac expressly states that the yellow needles obtained from the joint action of cyanogen and sulphuretted hydrogen, are " composed of one volume of cyanogen, and 1½ volume of sulphuretted hydrogen." So that instead of containing no hydrogen, this substance contains half a volume *more* than hydrocyanic acid.

The sulphuroprussiates have been examined only by Mr. Porrett. That of the red oxide of iron is a deliquescent salt, of a beautiful crimson colour. It may be obtained in a solid form by an atmosphere artificially dried. A concise account of these salts is given in the 5th Vol. of the Annals of Philos.*

* ACID (PURPURIC). The excrements of the serpent *Boa Constrictor*, consist of pure lithic acid. Dr. Prout found that on digesting this substance thus obtained, or from urinary calculi, in dilute nitric acid, an effervescence takes place, and the lithic acid is dissolved, forming a beautiful purple liquid. The excess of nitric acid being neutralized with ammonia, and the whole concentrated by slow evaporation, the colour of the solution becomes of a deeper purple, and dark red granular crystals, sometimes of a greenish hue externally, soon begin to separate in abundance. These crystals are a compound of ammonia with the acid principle in question. The ammonia was displaced by digesting the salt in a solution of caustic potash, till the red colour entirely disappeared. This alkaline solution was then gradually dropped into dilute sulphuric acid, which, uniting with the potash, left the acid principle in a state of purity.

This acid principle is likewise produced from lithic acid by chlorine, and also, but with more difficulty, by iodine. Dr. Prout, the discoverer of this new acid has, at the suggestion of Dr. Wollaston, called it purpuric acid, because its saline compounds have for the most part a red or purple colour.

This acid, as obtained by the preceding process, usually exists in the form of a very fine powder, of a slightly yellowish or cream colour; and when examined with a magnifier, especially under water, appears to possess a pearly lustre. It has no smell, nor taste. Its spec. grav. is considerably above water. It is scarcely soluble in water. One-tenth of a grain, boiled for a considerable time in 1000 grains of water, was not entirely dissolved. The water, however, assumed a purple tint, probably, Dr. Prout thinks, from the formation of a little purpurate of ammonia. Purpuric acid is insoluble in alcohol and ether. The mineral acids dissolve it only when they are concentrated. It does not affect litmus paper. By igniting it in contact with oxide of copper, he determined its composition to be,

2 atoms hydrogen,	0.250	- -	4.54
2 carbon,	1.500	- -	27.27
2 oxygen,	2.000	- -	36.36
1 azote,	1.750	- -	31.81
	5.50		99.98

Purpuric acid combines with the alkalis, alkaline earths, and metallic oxides. It is capable of expelling carbonic acid from the alkaline carbonates by the assistance of heat, and does not combine with any other acid. These are circumstances sufficient, as Dr. Wollaston observed, to distinguish it from an oxide, and to establish its character as an acid.

Purpurate of ammonia crystallizes in quadrangular prisms, of a deep garnet-red colour. It is soluble in 1500 parts of water at 60°, and in much less at the boiling temperature. The solution is of a beautiful deep carmine, or rose-red colour. It has a slightly sweetish taste, but no smell. Purpurate of potash is much more soluble; of soda is less; that of lime is nearly insoluble; those of strontian and lime are slightly soluble. All the solutions have the characteristic colour. Purpurate of magnesia is very soluble; and in solution, of a very beautiful colour. A solution of acetate of zinc produces with purpurate of ammonia, a solution and precipitate of a beautiful gold-yellow colour; and a most brilliant iridescent pellicle, in which green and yellow predominate, forms on the surface of the solution. Dr. Prout conceives the salts to be anhydrous, or void of water, and composed of two atoms of acid and one of base. The purpuric acid and its compounds probably constitute the bases of many animal and vegetable colours. The well known pink sediment which generally appears in the urine of those labouring under febrile affections, appears to owe its colour chiefly to the purpurate of ammonia, and perhaps occasionally to the purpurate of soda.

The solution of lithic acid in nitric acid stains the skin of a permanent colour, which becomes of a deep purple on exposure to the sun. These apparently sound experimental deductions of Dr. Prout, have been called in question by M. Vauquelin; but Dr. Prout ascribes M. Vauquelin's failure, in attempting to procure purpuric acid, to his having operated on an impure lithic acid. We think entire confidence may be put in Dr. Prout's experiments. He says that it is difficult to obtain purpuric acid from the lithic acid of urinary concretions.—*Phil. Trans. for* 1818. *and Annals of Phil.* vol. 14.*

Acid (Pyroligneous). In the destructive distillation of any kind of wood, an acid is obtained, which was formerly called *acid spirit of wood*, and since pyroligneous acid. * Fourcroy and Vauquelin showed that this acid was merely the acetic, contaminated with empyreumatic oil and bitumen. See Acetic Acid.

Under acetic acid will be found a full account of the production and purification of pyrolignous acid. We shall add here, that M. Monge discovered, about two years ago, that this acid has the property of preventing the decomposition of animal substances. It is sufficient to plunge meat for a few moments into this acid, even slightly empyreumatic, to preserve it as long as you please. "Putrefaction," it is said, "not only stops, but retrogrades." To the empyreumatic oil a part of this effect has been ascribed; and hence has been accounted for, the agency of smoke in the preservation of tongues, hams, herrings, &c. Dr. Jorg of Leipsic has entirely recovered several anatomical preparations from incipient corruption by pouring this acid over them. With the empyreumatic oil or tar he has smeared pieces of flesh already advanced in decay, and notwithstanding that the weather was hot, they soon became dry and sound. To the above statements Mr. Ramsay of Glasgow, an eminent manufacturer of pyrolignous acid, and well known for the purity of his vinegar from wood, has recently added the following facts in the 5th number of the Edinburgh Philosophical Journal. If fish be simply dipped in redistilled pyrolignous acid, of the specific gravity 1.012, and afterwards dried in the shade, they preserve perfectly well. On boiling herrings treated in this manner, they were very agreeable to the taste, and had nothing of the disagreeable empyreuma which those of his earlier experiments had, which were steeped for three hours in the acid. A number of very fine haddocks were cleaned, split, and slightly sprinkled with salt for six hours. After being drained, they were dipped for about three seconds in pyrolignous acid, then hung up in the shade for six days. On being broiled, the fish were of an uncommonly fine flavour, and delicately white. Beef treated in the same way, had the same flavour as Hamburgh beef, and kept as well. Mr. Ramsay has since found, that his perfectly purified vinegar, specific gravity 1.034 being applied by a cloth or sponge to the surface of fresh meat, makes it keep sweet and sound for several days longer in summer than it otherwise would. Immersion for a minute in his purified common vinegar, specific gravity 1.009, protects beef and fish from all taint in summer, provided they be hung up and dried in the shade. When, by frequent use, the pyrolignous acid has become impure, it may be clarified by beating up twenty gallons of it with a dozen of eggs in the usual manner, and heating the mixture in an iron boiler. Before boiling, the eggs coagulate, and bring the impurities to the surface of the boiler, which are of course to be carefully skimmed off. The acid must immediately be withdrawn from the boiler, as it acts on iron.*

* Acid (Pyrolithic). When uric acid concretions are distilled in a retort, silvery white plates sublime. These are pyrolithate of ammonia. When their solution is poured into that of subacetate of lead, a pyrolithate of lead falls, which, after proper washing, is to be shaken with water, and decomposed by sulphuretted hydrogen gas. The supernatant liquid is now a solution of pyrolithic acid, which yields small acicular crystals by evaporation. By heat these melt and sublime in white needles. They are soluble in four parts of cold water, and the solution reddens vegetable blues. Boiling alcohol dissolves the acid, but on cooling it deposites it, in small white grains. Nitric acid dissolves without changing it. Hence, pyrolithic is a different acid from the lithic, which, by nitric acid, is convertible into purpurate of ammonia. The pyrolithate of lime crystallizes in stalactites, which have a bitter and slightly acrid taste. It consists of 91.4 acid + 8.6 lime. Pyrolithate of barytes is a nearly insoluble powder. The salts of pot-

ash, soda, and ammonia, are soluble, and the former two crystallizable. At a red heat, and by passing it over ignited oxide of copper, it is decomposed, into oxygen 44.32, carbon 28.29, azote 16.84, hydrogen 10.*

* Acid (Pyromalic). When malic or sorbic acid, for they are the same, is distilled in a retort, an acid sublimate, in white needles, appears in the neck of the retort, and an acid liquid distils into the receiver. This liquid, by evaporation, affords crystals, constituting a peculiar acid, to which the above name has been given.

They are permanent in the air, melt at 118° Fahr., and on cooling, form a pearl coloured mass of diverging needles. When thrown on red hot coals, they completely evaporate in an acrid, cough-exciting smoke. Exposed to a strong heat in a retort, they are partly sublimed in needles, and are partly decomposed. They are very soluble in strong alcohol, and in double their weight of water, at the ordinary temperature. The solution reddens vegetable blues, and yields white flocculent precipitates with acetate of lead and nitrate of mercury; but produces no precipitate with lime-water. By mixing it with barytes-water, a white powder falls, which is redissolved by dilution with water, after which, by gentle evaporation, the pyromalate of barytes may be obtained in silvery plates. These consist of 100 acid, and 185.142 barytes, or in prime equivalents, of 5.24 + 9.70.

Pyromalate of potash may be obtained in feather formed crystals, which deliquesce. Pyromalate of lead forms first a white flocculent precipitate, soon passing into a semi-transparent jelly, which by dilution and filtration from the water, yields brilliant pearly looking needles. The white crystals that sublime in the original distillation, are considered by M. Lassaigne as a peculiar acid.*

* Acid (Pyrotartaric). Into a coated glass retort introduce tartar, or rather tartaric acid, till it is half full, and fit to it a tubulated receiver. Apply heat, which is to be gradually raised to redness. Pyrotartaric acid of a brown colour, from impurity, is found in the liquid products. We must filter these through paper previously wetted, to separate the oily matter. Saturate the liquid with carbonate of potash; evaporate to dryness; redissolve, and filter through clean moistened paper. By repeating this process of evaporation, solution, and filtration, several times, we succeed in separating all the oil. The dry salt is then to be treated in a glass retort, at a moderate heat, with dilute sulphuric acid. There passes over into the receiver, first of all a liquor containing evidently acetic acid; but towards the end of the distillation, there is condensed in the vault of the retort, a white and foliated sublimate, which is the pyrotartaric acid, perfectly pure.

It has a very sour taste, and reddens powerfully the tincture of turnsole. Heated in an open vessel, the acid rises in a white smoke, without leaving the charcoaly residuum, which is left in a retort. It is very soluble in water, from which it is separated in crystals by spontaneous evaporation. The bases combine with it, forming pyrotartrates, of which those of potash, soda, ammonia, barytes, strontites, and lime, are very soluble. That of potash is deliquescent, soluble in alcohol, capable of crystallizing in plates, like the acetate of potash. This pyrotartrate precipitates both acetate of lead and nitrate of mercury, whilst the acid itself precipitates only the latter. Rose is the discoverer of this acid, which was formerly confounded with the acetic.*

* Acid (Rosasic). There is deposited from the urine of persons labouring under intermittent and nervous fevers, a sediment of a rose colour, occasionally in reddish crystals. This was first discovered to be a peculiar acid by M. Proust, and afterwards examined by M. Vauquelin. This acid is solid, of a lively cinnabar hue, without smell, with a faint taste, but reddening litmus very sensibly. On burning coal it is decomposed into a pungent vapour, which has not the odour of burning animal matter. It is very soluble in water, and it even softens in the air. It is soluble in alcohol. It forms soluble salts with potash, soda, ammonia, barytes, strontites, and lime. It gives a slight rose-coloured precipitate with acetate of lead. It also combines with lithic acid, forming so intimate a union, that the lithic acid in precipitating from urine carries the other, though a deliquescent substance, down along with it. It is obtained pure by acting on the sediment of urine with alcohol. See Acid (Purpuric).*

* Acid (Saclactic). See Acid (Mucic).*

* Acid (Sebacic). Subject, to a considerable heat, 7 or 8 pounds of hog's lard, in a stoneware retort capable of holding double the quantity, and connect its beak by an adopter with a cooled receiver. The condensible products are chiefly fat, altered by the fire, mixed with a little acetic and sebacic acids. Treat this product with boiling water several times, agitating the liquor, allowing it to cool and decanting each time. Pour at last, into the watery liquid, solution of acetate of lead in excess. A white flocculent precipitate of sebate of lead will instantly fall, which must be collected on a filter, washed, and dried. Put the sebate of lead into a phial,

and pour upon it its own weight of sulphuric acid, diluted with five or six times its weight of water. Expose this phial to a heat of about 212°. The sulphuric acid combines with the oxide of lead, and sets the sebacic acid at liberty. Filter the whole while hot. As the liquid cools, the sebacic acid crystallizes, which must be washed, to free it completely from the adhering sulphuric acid. Let it be then dried at a gentle heat.

The sebacic acid is inodorous; its taste is slight, but it perceptibly reddens litmus paper; its specific gravity is above that of water, and its crystals are small white needles of little coherence. Exposed to heat, it melts like fat, is decomposed, and partially evaporated. The air has no effect upon it. It is much more soluble in hot than in cold water; hence boiling water saturated with it, assumes a nearly solid consistence on cooling. Alcohol dissolves it abundantly at ordinary temperature.

With the alkalis it forms soluble neutral salts; but if we pour into their concentrated solutions, sulphuric, nitric, or muriatic acids, the sebacic is immediately deposited in large quantity. It affords precipitates with the acetates and nitrates of lead, mercury, and silver.

Such is the account given by M. Thenard of this acid, in the 3d volume of his Traité de Chimie, published in 1815. Berzelius, in 1806, published an elaborate dissertation, to prove that M. Thenard's new sebacic acid was only the benzoic, contaminated by the fat, from which, however, it may be freed, and brought to the state of common benzoic acid. M. Thenard takes no notice of M. Berzelius whatever, but concludes his account by stating, that it has been known only for twelve or thirteen years, and that it must not be confounded with the acid formerly called sebacic, which possesses a strong disgusting odour, and was merely acetic or muriatic acid, or fat, which had been changed in some way or other, according to the process used in the preparation.*

* Acid (Sorbic). The acid of apples, called malic, may be obtained most conveniently and in greatest purity from the berries of the mountain ash, called *sorbus*, or *pyrus aucuparia*, and hence the present name, sorbic acid. This was supposed to be a new and peculiar acid by Mr. Donovan and M. Vauquelin, who wrote good dissertations upon it. But it now appears that the sorbic and *pure* malic acids are identical.

Bruise the ripe berries in a mortar, and then squeeze them in a linen bag. They yield nearly half their weight of juice, of the specific gravity of 1.077. This viscid juice, by remaining for about a fortnight in a warm temperature, experiences the vinous fermentation, and would yield a portion of alcohol. By this change, it has become bright, clear, and passes easily through the filter, while the sorbic acid itself is not altered. Mix the clear juice with filtered solution of acetate of lead. Separate the precipitate on a filter, and wash it with cold water. A large quantity of boiling water is then to be poured upon the filter, and allowed to drain into glass jars. At the end of some hours, the solution deposites crystals of great lustre and beauty. Wash these with cold water, dissolve them in boiling water, filter, and crystallize. Collect the new crystals, and boil them for half an hour in 2.3 times their weight of sulphuric acid, specific gravity 1.090, supplying water as fast as it evaporates, and stirring the mixture diligently with a glass rod. The clear liquor is to be decanted into a tall narrow glass jar, and while still hot, a stream of sulphuretted hydrogen is to be passed through it. When the lead has been all thrown down in a sulphuret, the liquid is to be filtered, and then boiled in an open vessel to dissipate the adhering sulphuretted hydrogen. It is now a solution of sorbic acid.

When it is evaporated to the consistence of a sirup, it forms mammelated masses of a crystalline structure. It still contains a considerable quantity of water, and deliquesces when exposed to the air. Its solution is transparent, colourless, void of smell, but powerfully acid to the taste. Lime and barytes waters are not precipitated by solution of the sorbic acid, although the sorbate of lime is nearly insoluble. One of the most characteristic properties of this acid, is the precipitate which it gives with the acetate of lead, which is at first white and flocculent, but afterwards assumes a brilliant crystalline appearance. With potash, soda, and ammonia, it forms crystallizable salts containing an excess of acid. That of potash is deliquescent. Sorbate of barytes consists, according to M. Vauquelin, of 47 sorbic acid, and 53 barytes in 100. Sorbate of lime well dried, appeared to be composed of 67 acid + 33 lime = 100. Sorbate of lead, which in solution, like most of the other sorbates, retains an acidulous taste, consists in the dried state of 33 acid + 67 oxide of lead in 100. The ordinary sorbate contains 12.5 per cent of water. M. Vauquelin says that Mr. Donovan was mistaken in supposing that he had obtained super and subsorbates of lead. There is only one salt with this base, according to M. Vauquelin. It is nearly insoluble in cold water; but a little more so in boiling water: as it cools it crystallizes in the beautiful white, brilliant, and shining needles, of which we have already spoken. A remarkable phenomenon occurs, when sorbate of lead is boiled in water. Whilst one part of the salt saturates the water, the other part, for want of a sufficient quantity of fluid to dissolve it, is partially melted, and is at first kept on the surface by the force of ebullition, but after some time falls to the bottom, and as it cools becomes strongly fixed to the vessel.

To procure sorbic acid, M. Braconnot saturates with chalk the juice of the scarcely ripe berries, evaporates to the consistence of a sirup, removing the froth; and a granular sorbate falls, which he decomposes by carbonate of soda. The sorbate of soda is freed from colouring matter by a little lime, strained, freed from lime by carbonic acid gas, and decomposed by subacetate of lead, and treated as above.

M. Vauquelin analyzed the acid, in the dry sorbates of copper and lead.

The following are its constituents:

Hydrogen,	16.8
Carbon,	28.3
Oxygen,	54.9
	100.0

M. Vauquelin's analysis of the sorbate of lead gives 7.0 for the prime equivalent of this acid; the sorbate of lime gives 7.230; and the sorbate of barytes 8.6. If we take that of lime for the standard, as it was the only one quite neutral, we shall have the following relation of prime equivalents:

		Theory.	Exp.
4 of oxygen	= 4.00	53.3	54.9
3 of carbon	= 2.25	30.0	28.3
10 of hydrogen	= 1.25	16.7	16.8
	7.50	100.0	100.0

The approximation of these sets of proportions, illustrates and confirms the accuracy of M. Vauquelin's researches.

The calcareous salt having been procured in a neutral state, by the addition of carbonate of potash to its acidulous solution, it might readily be mixed with as much carbonate of lime as would diminish the apparent equivalent of acid from 7.50 to 7.230; especially as the barytic compound gives no less than 8.6. Had the composition of the sorbate of lime been 67.7 and 32.3, instead of 67 and 33, the prime equivalent of the acid would come out 7.5, as its ultimate analysis indicates.

As the pure sorbic acid appears to be without odour, without colour, and of an agreeable taste, it might be substituted for the tartaric and citric, in medicine and the arts.

The same acid may be got from apples, in a similar way.*

Acid (Suberic). This acid was obtained by Brugnatelli from cork, and afterwards more fully examined by Bouillon la Grange. To procure it, pour on cork, grated to powder, six times its weight of nitric acid, of the specific gravity of 1.26, in a tubulated retort, and distil the mixture with a gentle heat, as long as any red fumes arise. As the distillation advances, a yellow matter, like wax, appears on the surface of the liquid in the retort. While its contents continue hot, pour them into a glass vessel, placed on a sand-heat, and keep them continually stirring with a glass rod; by which means the liquid will gradually grow thicker. As soon as white penetrating vapours appear, let it be removed from the sand-heat, and kept stirring till cold. Thus an orange-coloured mass will be obtained, of the consistence of honey, of a strong sharp smell while hot, and a peculiar aromatic smell when cold. On this, pour twice its weight of boiling water, apply heat till it liquefies, and filter. As the filtered liquor cools, it deposites a powdery sediment, and acquires a thin pellicle. Separate the sediment by filtration, and evaporate the fluid nearly to dryness. The mass thus obtained is the suberic acid, which may be purified by saturating with an alkali, and precipitating by an acid, or by boiling it with charcoal powder.

* M. Chevreul obtained the suberic acid by mere digestion of the nitric acid on grated cork, without distillation, and purified it by washing with cold water. 12 parts of cork may be made to yield 1 of acid. When pure, it is white and pulverulent, having a feeble taste, and little action on litmus. It is soluble in 80 parts of water at 55½° F. and in 38 parts at 140°. It is much more soluble in alcohol, from which water throws down a portion of the suberic acid. It occasions a white precipitate when poured into acetate of lead, nitrates of lead, mercury, and silver, muriate of tin, and protosulphate of iron. It affords no precipitate with solutions of copper or zinc. The suberates of potash, soda, and ammonia, are very soluble. The two latter may be readily crystallized. Those of barytes, lime, magnesia, and alumina, are of sparing solubility.*

Acid (Succinic.) It has long been known that amber, when exposed to distillation, affords a crystallized substance, which sublimes into the upper part of the vessel. Before its nature was understood it was called *salt of amber*; but it is now known to be a peculiar acid, as Boyle first discovered. The crystals are at first contaminated with a little oil, which gives them a brownish colour; but they may be purified by solution and crystallization, repeated as often as necessary, when they will become transparent and shining. Pott recommends to put on the filter, through which the solution is passed, a little cotton previously wetted with oil of amber. Their figure is that of a triangular prism. Their taste is acid, and they redden the blue colour of litmus, but not that of violets. They are soluble in less than two parts of boiling alcohol, in two parts of boiling water, and in twenty-five of cold water.

M. Planche of Paris observes, that a considerable quantity might be collected in making amber varnish, as it sublimes while the amber is melting for this purpose, and is wasted.

* Several processes have been proposed for purifying this acid: that of Richter appears to be the best. The acid being dissolved in hot water, and filtered, is to be saturated with potash or soda, and boiled with charcoal, which absorbs the oily matter. The solution being filtered, nitrate of lead is added; whence results an insoluble succinate of lead, from which, by digestion in the equivalent quantity of sulphuric acid, pure succinic acid is separated. Nitrate or muriate of barytes, will show whether any sulphuric acid remains mixed with the succinic solution; and if so, it may be withdrawn by digesting the liquid with a little more succinate of lead. Pure succinic acid may be obtained by evaporation, in white transparent prismatic crystals. Their taste is somewhat sharp, and they redden powerfully tincture of turnsole. Heat melts and partially decomposes succinic acid. Air has no effect upon it. It is soluble in both water and alcohol, and much more so when they are heated. Its prime equivalent, by Berzelius, is 6.26; and it is composed of 4.51 hydrogen, 47.6 carbon, 47.888 oxygen in 100, or 2 + 4 + 3 primes.*

With barytes and lime the succinic acid forms salts but little soluble; and with magnesia it unites into a thick gummy substance. The succinates of potash and ammonia are crystallizable and deliquescent; that of soda does not attract moisture. The succinate of ammonia is useful in analysis to separate oxide of iron.

* **Acid (Sulphovinic.)** The name given by Vogel to an acid, or class of acids, which may be obtained by digesting alcohol and sulphuric acid together with heat. It seems probable, that this acid is merely the hypo-sulphuric, combined with a peculiar oily matter.*

Acid (Sulphuric.) When sulphur is heated to 180° or 190° in an open vessel, it melts, and soon afterward emits a bluish flame, visible in the dark, but which, in open day-light, has the appearance of a white fume. This flame has a suffocating smell, and has so little heat that it will not set fire to flax, or even gunpowder, so that in this way the sulphur may be entirely consumed out of it. If the heat be still augmented, the sulphur boils, and suddenly bursts into a much more luminous flame, the same suffocating vapour still continuing to be emitted.

The suffocating vapour of sulphur is imbibed by water, with which it forms the fluid formerly called *volatile vitriolic*, now sulphurous acid. If this fluid be exposed for a time to the air, it loses the sulphureous smell it had at first, and the acid becomes more fixed. It is then the fluid which was formerly called the *spirit of vitriol*. Much of the water may be driven off by heat, and the dense acid which remains is the sulphuric acid, commonly called *oil of vitriol*; a name which was probably given to it from the little noise it makes when poured out, and the unctuous feel it has when rubbed between the fingers, produced by its corroding and destroying the skin, with which it forms a soapy compound.

The stone or mineral called martial pyrites, which consists for the most part of sulphur and iron, is found to be converted into the salt vulgarly called *green vitriol*, but more properly sulphate of iron, by exposure to air and moisture. In this natural process the pyrites breaks and falls in pieces; and if the change take place rapidly, a considerable increase of temperature follows, which is sometimes sufficient to set the mass on fire. By conducting this operation in an accurate way, it is found that oxygen is absorbed. The sulphate is obtained by solution in water, and subsequent evaporation; by which the crystals of the salt are separated from the earthy impurities, which were not suspended in the water.

The sulphuric acid was formerly obtained in this country by distillation from sulphate of iron, as it still is in many parts abroad: the common green vitriol is made use of for this purpose, as it is to be met with at a low price, and the acid is most easily to be extracted from it. With respect to the operation itself, the following particulars should be attended to: First, the vitriol must be calcined in an iron or earthen vessel, till it appears of a yellowish red colour: by this operation it will lose half its weight. This is done in order to deprive it of the greater part of the water which it has attracted into its crystals during the crystallization, and which would otherwise, in the ensuing distillation, greatly weaken the acid. As soon as the calcination is finished, the vitriol is to be put immediately, while it is warm, into a coated earthen retort, which is to be filled two-thirds with it, so that the ingredients may have sufficient room upon being distended by the heat, and thus the bursting of the retort be prevented. It will be most advisable to have the retort immediately enclosed in brick-work in a reverberatory furnace, and to stop up the neck of it till the distillation begins, in order to prevent the materials from attracting fresh humidity from the air. At the beginning of the distillation the retort must be opened, and a moderate fire is to be applied to it, in order to expel from the vitriol all that part of the phlegm which does not taste strongly of the acid, and which may be received in an open vessel placed under the retort. But as soon as there appear any acid drops, a receiver is to be added, into which has been previously poured a quantity of the acidulous fluid which has come over, in the proportion of half a pound of it to twelve pounds of the calcined vitriol; when the receiver is to be secured with a proper luting. The fire is now to be raised by little and little to the most intense degree of heat, and the receiver carefully covered with wet cloths, and, in winter time, with snow or ice, as the acid rises in the form of a thick white vapour, which toward the end of the operation becomes hot, and heats the receiver to a great degree. The fire must be continued at this high pitch for several days, till no vapour issues from the retort, nor any drops are seen trickling down its sides. In the case of a great quantity of vitriol being distilled, M. Bernhardt has observed it to continue emitting vapours in this manner for the space of ten days. When the vessels are quite cold, the receiver must be opened carefully, so that none of the luting may fall into it; after which the fluid contained in it is to be poured into a bottle, and the air carefully excluded. The fluid that is thus obtained is the German sulphuric acid, of which Bernhardt got sixty-four pounds from six hundred weight of vitriol; and on the other hand, when no water had been previously poured into the receiver, fifty-two pounds only of a dry concrete acid. This acid was formerly called *glacial oil of vitriol*, and its consistence is owing to a mixture of sulphurous acid, which occasions it to become solid at a moderate temperature.

* It has been lately stated by Vogel, that when this fuming acid is put into a glass retort, and distilled by a moderate heat into a receiver cooled with ice, the fuming portion comes over first, and may be obtained in a solid state by stopping the distillation in time. This has been supposed to constitute absolute sulphuric acid, or acid entirely void of water. It is in silky filaments, tough, difficult to cut, and somewhat like asbestos. Exposed to the air, it fumes strongly, and gradually evaporates. It does not act on the skin so rapidly as concentrated oil of vitriol. Up to 66° it continues solid, but at temperatures above this it becomes a colourless vapour, which whitens on contact with air. Dropped into water in small quantities, it excites a hissing noise, as if it were red hot iron; in larger quantities it produces a species of explosion. It is said to be convertible into ordinary sulphuric acid, by the addition of a fifth of water. It dissolves sulphur, and assumes a blue, green, or brown colour, according to the proportion of sulphur dissolved. The specific gravity of the black fuming sulphuric acid, prepared in large quantities from copperas, at Nordhausen, is 1.896. Its constitution is not well ascertained.*

The sulphuric acid made in Great Britain is produced by the combustion of sulphur. There are three conditions requisite in this operation. Oxygen must be present to maintain the combustion; the vessel must be so close as to prevent the escape of the volatile matter which rises, and water must be present to imbibe it. For these purposes, a mixture of eight parts of sulphur with one of nitre is placed in a proper vessel, enclosed within a chamber of considerable size, lined on all sides with lead, and covered at bottom with a shallow stratum of water. The mixture being set on fire, will burn for a considerable time by virtue of the supply of oxygen which nitre gives out when heated, and the water imbibing the sulphurous vapours, becomes gradually more and more acid after repeated combustions, and the acid is afterward concentrated by distillation.

* Such was the account usually given of this operation, till MM. Clement and Desormes showed, in a very interesting memoir, its total inadequacy to account for the result. 100 parts of nitre, judiciously managed, will produce, with the requisite quantity of sulphur, 2000 parts of concentrated sulphuric acid. Now these contain 1200 parts of oxygen, while the hundred parts of nitre contain only 39⅓ of oxygen; being not $\frac{1}{30}$th part of what is afterwards found in the resulting sulphuric acid. But after the combustion of the sulphur, the nitre is converted into sulphate and bisulphate of potash, which mingled residuary salts contain nearly as much oxygen as the nitre originally did. Hence, the origin of the 1200 parts of the oxygen in the sulphuric acid is still to be sought for. The following ingenious theory was first given by MM. Clement and Desormes. The burning sulphur, or sulphurous acid, taking from the nitre a portion of its oxygen, forms sulphuric acid, which unites with the potash, and displaces a little nitrous and nitric acids in vapour. These vapours are decomposed, by the sulphurous acid, into nitrous gas, or deutoxide of azote. This gas, naturally little denser than air, and now expanded by the heat, suddenly rises

to the roof of the chamber; and might be expected to escape at the aperture there, which manufacturers were always obliged to leave open, otherwise they found the acidification would not proceed. But the instant that nitrous gas comes in contact with atmospherical oxygen, nitrous acid vapour is formed, which being a very heavy aeriform body, immediately precipitates on the sulphurous flame, and converts it into sulphuric acid; while itself resuming the state of nitrous gas, reascends for a new charge of oxygen, again to redescend, and transfer it, to the flaming sulphur. Thus we see, that a small volume of nitrous vapour, by its alternate metamorphoses into the states of oxide and acid, and its consequent interchanges, may be capable of acidifying a great quantity of sulphur.

This beautiful theory received a modification from Sir H. Davy. He found that nitrous gas had no action on sulphurous gas, to convert it into sulphuric acid, unless water be present. With a *small* proportion of water, 4 volumes of sulphurous acid gas, and 3 of nitrous gas, are condensed into a crystalline solid, which is instantly decomposed by *abundance* of water; oil of vitriol is formed, and nitrous acid given off, which with contact of air becomes nitrous acid gas, as above described. The process continues, according to the same principle of combination and decomposition, till the water at the bottom of the chamber is become strongly acid. It is first concentrated in large leaden pans, and afterwards in glass retorts heated in a sand-bath. Platinum alembics, placed within pots of cast-iron of a corresponding shape and capacity, have been lately substituted in many manufactories for glass, and have been found to save fuel, and quicken the process of concentration.

The proper mode of burning the sulphur with the nitre, so as to produce the greatest quantity of oil of vitriol, is a problem, concerning which chemists hold a variety of opinions. M. Thenard describes the following as the best. Near one of the sides of the leaden chamber, and about a foot above its bottom, an iron plate, furnished with an upright border, is placed horizontally over a furnace, whose chimney passes across, under the botton of the chamber, without having any connexion with it. On this plate, which is enclosed in a little chamber, the mixture of sulphur and nitre is laid. The whole being shut up, and the bottom of the large chamber covered with water, a gentle fire is kindled in the furnace. The sulphur soon takes fire, and gives birth to the products described. When the combustion is finished, which is seen through a little pane adapted to the trap-door of the chamber, this is opened, the sulphate of potash is withdrawn, and is replaced by a mixture of sulphur and nitre. The air in the great chamber is meanwhile renewed, by opening its lateral door, and a valve in its opposite side. Then, after closing these openings, the furnace is lighted anew. Successive mixtures are thus burned till the acid acquires a specific gravity of about 1.390, taking care never to put at once on the plate more sulphur than the air of the chamber can acidify. The acid is then withdrawn by stopcocks, and concentrated.

The following details are extracted from a paper on sulphuric acid by Dr. Ure, which was published in the 4th volume of the Journal of Science and the Arts.

The best commercial sulphuric acid that I have been able to meet with, contains from one-half to three quarters of a part in the hundred, of solid saline matter, foreign to its nature. These fractional parts consist of sulphate of potash and lead, in the proportion of four of the former to one of the latter. It is, I believe, difficult to manufacture it directly, by the usual methods, of a purer quality. The ordinary acid sold in the shops contains often 3 or 4 per cent. of saline matter. Even more is occasionally introduced, by the employment of nitre, to remove the brown colour given to the acid by carbonaceous matter. The amount of these adulterations, whether accidental or fraudulent, may be readily determined by evaporating, in a small capsule of porcelain, or rather platinum, a definite weight of the acid. The platinum cup, placed on the red cinders of a common fire, will give an exact result in five minutes. If more than five grains of matter remain from five hundred of acid, we may pronounce it sophisticated.

Distillation is the mode by which pure oil of vitriol is obtained. This process is described in chemical treatises as both difficult and hazardous; but since adopting the following plan, I have found it perfectly safe and convenient. I take a plain glass retort, capable of holding from two to four quarts of water, and put into it about a pint measure of the sulphuric acid, (and a few fragments of glass,) connecting the retort with a large globular receiver, by means of a glass tube four feet long, and from one to two inches in diameter. The tube fits very loosely at both ends. The retort is placed over a charcoal fire, and the flame is made to play gently on its bottom. When the acid begins to boil smartly, sudden explosions of dense vapour, rush forth from time to time, which would infallibly break small vessels. Here, however, these expansions are safely permitted, by the large capacity of the retort and receiver, as well as by the easy communication with the air at both ends of the adopter tube. Should the retort, indeed, be exposed to a great intensity of flame, the vapour will no doubt be generated with incoercible rapidity, and break the apparatus. But this accident can proceed only from gross imprudence. It resembles, in suddenness, the explosion of gunpowder, and illustrates admirably Dr. Black's observation, that, but for the great latent heat of steam, a mass of water, powerfully heated, would explode on reaching the boiling temperature. I have ascertained that the specific caloric of the vapour of sulphuric acid is very small, and hence the danger to which rash operators may be exposed during its distillation. Hence, also, it is unnecessary to surround the receiver with cold water, as when alcohol and most other liquids are distilled. Indeed the application of cold to the bottom of the receiver generally causes it, in the present operation to crack. By the above method, I have made the concentrated oil of vitriol flow over in a continuous slender stream, without the globe becoming sensibly hot.

I have frequently boiled the *distilled* acid till only one-half remained in the retort; yet at the temperature of 60° Fahrenheit, I have never found the specific gravity of acid so concentrated, to exceed 1.8455. It is, I believe, more exactly 1.8452. The number 1.850, which it has been the fashion to assign for the density of pure oil of vitriol, is undoubtedly very erroneous, and ought to be corrected. Genuine *commercial* acid should never surpass 1.8485; when it is denser, we may infer sophistication, or negligence, in the manufacture.

The progressive increase of its density, with saline contamination, will be shown by the following experiments. To 4100 grains of genuine commercial acid (but concentrated to only 1.8350) 40 grains of dry sulphate of potash were added. When the solution was completed, the specific gravity at 60° had become 1.8417. We see that at these densities the addition of 0.01 of salt increases the specific gravity by about 0.0067. To the above 4140 grains other 80 grains of sulphate were added, and the specific gravity, after solution, was found to be 1.8526. We perceive that somewhat more salt is now required to produce a proportional increase of density; 0.01 of the former changing the latter by only 0.0055. Five hundred grains of this acid being evaporated in a platinum capsule left 16½ grains, whence the composition was

Sulphate of potash, with a little sulphate of lead, - - - -	3.30
Water of dilution, - -	5.3
Oil of vitriol of 1.8485, -	91.4
	100.0

Thus, acid of 1.8526, which in commerce would have been accounted very strong, contained little more than 91 per cent of genuine acid.

Into the last acid more sulphate of potash was introduced, and solution being favoured by digestion in a moderate heat, the specific gravity became, at 60°, 1.9120. Of this compound, 300 grains, evaporated in the platinum capsule, left 41 grains of gently ignited saline matter. We have, therefore, nearly 14 per cent. On the specific gravity in this interval, an increase of 0.0054 was effected by 0.01 of sulphate. This liquid was composed of

Saline matter, - - - -	14.
Water of dilution, - -	4.7
Oil of vitriol of 1.8485, -	81.3
	100.0

The general proportion between the density and impurity may be stated at 0.0055 of the former, to 0.01 of the latter.

If from genuine oil of vitriol, containing ¾ of a per cent of saline matter, a considerable quantity of acid be distilled off, what remains in the retort will be found very dense. At the specific gravity 1.865, such acid contains 3½ of solid salt in the 100 parts. The rest is pure concentrated acid. From such heavy acid, at the end of a few days, some minute crystals will be deposited, after which its specific gravity becomes 1.860, and its transparency is perfect. It contains about 2½ per cent of saline matter. Hence if the chemist employ for his researches an acid, which, though originally pretty genuine, has been exposed to long ebullition, he will fall into great errors. From the last experiments it appears, that *concentrated* oil of vitriol can take up only a little saline matter in comparison with that which is somewhat dilute. It is also evident, that those who trust to specific gravity alone, for ascertaining the value of oil of vitriol, are liable to great impositions.

The saline impregnation exercises an important influence, on all the densities at subsequent degrees of dilution. Thus, the heavy impure *concentrated* acid, specific gravity 1.8650, being added to water in the proportion of one part to ten, by weight, gave, after twenty-four hours, a compound whose specific gravity was 1.064. But the most concentrated genuine acid, as well as distilled acid, by the same degree of dilution, namely 1 + 10, acquires the specific gravity of only 1.0602, while that of 1.852, containing, as stated above, 3½ per cent of sulphate of potash combined with acid of 1.835, gives, on a similar dilution, 1.058. This difference, though very obvious to good instruments, is inappreciable by ordinary commercial apparatus. Hence this mode of ascertaining the value of an acid, recommended by Mr. Dalton, is inadequate to detect a deterioration of even 8 or 9 per cent. Had a little more salt been present in the acid, the specific gravity of the dilute, in this case, would have equalled that of the genuine. On my acidimeter one per cent of deterioration could not fail to be detected, even by those ignorant of science.

The quantity of oxide, or rather sulphate of lead, which sulphuric acid can take up, is much more limited than is commonly imagined. To the concentrated oil of vitriol I added much carbonate of lead, and after digestion by a gentle heat, in a close vessel, for twenty-four hours, with occasional agitation, its specific gravity, when taken at 60°, was scarcely greater than before the experiment. It contained about 0.005 of sulphate of lead.

The quantity of water present in 100 parts of concentrated and pure oil of vitriol, seems to be pretty exactly 18 46.

In the experiments executed, to determine the relation between the density of diluted oil of vitriol, and its acid strength, I employed a series of phials, numbered with a diamond. Into each phial, recently boiled acid, and pure water, were mixed in the successive proportions of 99 + 1; 98 + 2; 97 + 3; &c. through the whole range of digits down to 1 acid + 99 water. The phials were occasionally agitated during 24 hours, after which the specific gravity was taken. The acid was genuine and well concentrated. Its specific gravity was 1.8485, Some of the phials were kept with their acid contents for a week or two, but no further change in the density took place. The strongest possible *distilled* acid was employed for a few points, and gave the same results as the other.

Of the three well known modes of ascertaining the specific gravity of a liquid, namely, that, by Fahrenheit's hydrometer; by weighing a vessel of known capacity filled with it; and by poising a glass ball, suspended by a fine platina wire from the arm of a delicate balance; I decidedly prefer the last. The corrosiveness, viscidity, and weight of oil of vitriol, render the first two methods ineligible; whereas, by a ball floating in a liquid, of which the specific gravity does not differ much from its own, the balance, little loaded, retains its whole sensibility, and will give the most accurate consistency of results.

In taking the specific gravity of concentrated or slightly diluted acid, the temperature must be minutely regulated, because, from the small specific heat of the acid, it is easily affected, and because it greatly influences the density. On removing the thermometer, it will speedily rise in the air to 75° or 80°, though the temperature of the apartment be only 60°. Afterwards it will slowly fall to perhaps 60° or 62°. If this thermometer, having its bulb covered with a film of dilute acid (from absorption of atmospheric moisture), be plunged into a strong acid, it will instantly rise 10°, or more, above the real temperature of the liquid. This source of embarrassment and occasional error is obviated by wiping the bulb after every immersion. An elevation of temperature, equal to 10° Fahr. diminishes the density of oil of vitriol by 0.005; 1000 parts being heated from 60° to 212°, become 1.043 in volume, as I ascertained by very careful experiments. The specific gravity, which was 1.848 becomes only 1.772, being the number corresponding to a dilution of 14 per cent of water. The viscidity of oil of vitriol, which below 50° is such as to render it difficult to determine the specific gravity by a floating ball, diminishes very rapidly as the temperature rises, evincing that it is a modification of cohesive attraction.

The following table of densities, corresponding to degrees of dilution, was the result, in each point, of a particular experiment, and was, moreover, verified in a number of its terms, by the further dilution of an acid, having previously combined with it a known proportion of water. The balance was accurate and sensible.

TABLE of the quantity of Oil of Vitriol and dry Sulphuric Acid in 100 parts of dilute, at different Densities, by Dr. URE.

Liq.	Sp. Gr.	Dry.	Liq.	Sp. Gr.	Dry	Liq.	Sp. Gr.	Dry.	Liq.	Sp. Gr.	Dry.
100	1.8485	81.54	75	1.6520	61.15	50	1.3884	40.77	25	1.1792	20.38
99	1.8475	80.72	74	1.6415	60.34	49	1.3788	39.95	24	1.1706	19.57
98	1.8460	79.90	73	1.6321	59.52	48	1.3697	39.14	23	1.1626	18.75
97	1.8439	79,09	72	1.6204	58.71	47	1.3612	38.32	22	1.1549	17.94
96	1.8410	78.28	71	1.6090	57.89	46	1.3530	37.51	21	1.1480	17.12
95	1.8376	77.46	70	1.5975	57.08	45	1.3440	36.69	20	1.1410	16.31
94	1.8336	76.65	69	1.5868	56.26	44	1.3345	35.88	19	1.1330	15.49
93	1.8290	75.83	68	1.5760	55.45	43	1.3255	35.06	18	1.1246	14,68
92	1.8233	75.02	67	1.5648	54.63	42	1.3165	34.25	17	1.1165	13.86
91	1.8179	74,20	66	1.5503	53.82	41	1,3080	33.43	16	1.1090	13.05
90	1,8115	73.39	65	1.5390	53.00	40	1.2999	32.61	15	1.1019	12.23
89	1.8043	72.57	64	1.5280	52.18	39	1.2913	31.80	14	1.0953	11.41
88	1.7962	71.75	63	1.5170	51.37	38	1.2826	30.98	13	1.0887	10.60
87	1.7870	70.94	62	1.5066	50.55	37	1.2740	30.17	12	1.0809	9.78
86	1.7774	70.12	61	1.4960	49.74	36	1.2654	29.35	11	1.0743	8.97
85	1.7673	69.31	60	1.4860	48.92	35	1.2572	28.54	10	1.0682	8.15
84	1.7570	68.49	59	1.4760	48.11	34	1.2490	27.72	9	1.0614	7.34
83	1.7465	67,68	58	1.4660	47.29	33	1.2409	26.91	8	1.0544	6,52
82	1.7360	66.86	57	1.4560	46.48	32	1.2334	26.09	7	1.0477	5.71
81	1,7245	66.05	56	1.4460	45.66	31	1.2260	25.28	6	1.0405	4.89
80	1.7120	65.23	55	1.4360	44.85	30	1.2184	24.46	5	1.0336	4.08
79	1.6993	64.42	54	1.4265	44.03	29	1.2108	23.65	4	1,0268	3.26
78	1.6870	63.60	53	1.4170	43.22	28	1.2032	22.83	3	1.0206	2.446
77	1,6750	62,78	52	1.4073	42.40	27	1,1956	22.01	2	1.0140	1.63
76	1.6630	61.97	51	1.3977	41.58	26	1.1876	21.20	1	1.0074	0.8154

In order to compare the densities of the preceding dilute acid, with those of distilled and again concentrated acid, I mixed one part of the latter with nine of pure water, and after agitation, and a proper interval, to ensure thorough combination, I found its specific gravity as above 1.0682; greater density indicates saline contamination.

Dilute acid having a specific gravity = 1.6321, has suffered the greatest condensation; 100 parts in bulk have become 92.14. If either more or less acid exist in the compound, the volume will be increased. What reason can be assigned for the maximum condensation occuring at this particular term of dilution? The above dilute acid consists of 73 per cent of oil of vitriol, and 27 of water. But 73 of the former contains, by this Table, 59.52 of dry acid, and 13.48 of water. Hence 100 of the dilute acid consist of 59.52 of dry acid, + 13.48 × 3 = 40.44 of water = 99.96; or it is a compound of one atom of dry acid, with three atoms of water. Dry sulphuric acid consists of three atoms of oxygen, united to one of sulphur. Here each atom of oxygen is associated with one of water, forming a symmetrical arrangement. We may therefore infer, that the least deviation from the above definite proportions, must impair the balance of the attractive forces, whence they will act less efficaciously, and therefore produce less condensation.

The very minute and patient examination which I was induced to bestow on the table of specific gravities, disclosed to me the general law pervading the whole, and consequently the means of inferring at once the density from the degree of dilution, as also of solving the inverse proposition.

If we take the specific gravity, corresponding to ten per cent of oil of vitriol, or 1.0682 as the root; then the specific gravities at the successive terms of 20, 30, 40, &c. will be the successive powers of that root. The terms of dilution are like logarithms, a series of numbers in in arithmetical progression, corresponding to another series, namely, the specific gravities in geometrical progression.

The simplest logarithmic formula which I have been able to contrive is the following.

$$\text{Log. } S = \frac{2a}{700},$$ where S is the specific gravity, and a the per centage of acid.

And $a = \text{Log. } S \times 350$.

In common language the two rules may be stated thus.

Problem 1st, To find the proportion of oil of vitriol in dilute acid of a given specific gravity. Multiply the logarithm of the specific gravity by 350, the product is directly the per centage of acid.

If the dry acid be sought, we must multiply the logarithm of the specific gravity by 285, and the product will be the answer.

Problem 2d, To find the specific gravity corresponding to a given proportion of acid. Multiply the quantity of acid by 2, and divide by 700; the quotient is the logarithm of the specific gravity.

Table of distilled sulphuric acid, for the higher points, below which it agrees with the former table.

Liquid Acid in 100.	Sp. Gr.	Dry Acid.
100	1.846	81.63
95	1.834	77.55
90	1.807	73.47
85	1.764	69.39
80	1.708	65.30
75	1.650	61.22*

The sulphuric acid strongly attracts water, which it takes from the atmosphere very rapidly, and in larger quantities, if suffered to remain in an open vessel, imbibing one-third of its weight in twenty-four hours, and more than six times its weight in a twelvemonth. If four parts by weight be mixed with one of water at 50°, they produce an instantaneous heat of 300° F.; and four parts raise one of ice to 212°; on the contrary, four parts of ice, mixed with one of acid, sink the thermometer to 4° below 0. When pure it is colourless, and emits no fumes. It requires a great degree of cold to freeze it; and if diluted with half a part or more of water, unless the dilution be carried very far, it becomes more and more difficult to congeal; yet at the specific gravity of 1.78, or a few hundredths above or below this, it may be frozen by surrounding it with melting snow. Its congelation forms regular prismatic crystals with six sides. Its boiling point, according to Bergmann, is 540°; according to Dalton, 590°.

* Sulphuric acid consists of three prime equivalents of oxygen, one of sulphur, and one of water; and by weight, therefore, of 3.0 oxygen + 2.0 sulphur + 1.125 water = 6.125, which represents the prime equivalent of the concentrated liquid acid; while 3 + 2 = 5, will be that of the dry acid.

Pure sulphuric acid is without smell and colour, and of an oily consistence. Its action on litmus is so strong, that a single drop of acid will redden an immense quantity. It is a most violent caustic; and has sometimes been administered with the most criminal purposes. The person who unfortunately swallows it, speedily dies in dreadful agonies and convulsions. Chalk, or common carbonate of magnesia, is the best antidote for this, as well as for the strong nitric and muriatic acids. When transmitted through an ignited porcelain tube of one-fith of an inch diameter, it is resolved into two parts of sulphurous acid gas, and one of oxygen gas, with water. Voltaic electricity causes an evolution of sulphur at the negative pole; whilst a sulphate of the metallic wire is formed at the positive. Sulphuric acid has no action on oxygen gas or air. It merely abstracts their aqueous vapour.

If the oxygenized muriatic acid of M. Thenard be put in contact with the sulphate of silver, there is immediately formed insoluble chloride of silver, and oxygenized sulphuric acid. To obtain sulphuric acid in the highest degree of oxygenation, it is merely necessary to pour barytes-water into the above oxygenized acid, so as to precipitate only a part of it, leaving the rest in union with the whole of the oxygen. Oxygenized sulphuric acid partially reduces the oxide of silver, occasioning a strong effervescence.

All the simple combustibles decompose sulphuric acid, with the assistance of heat. About 400° Fahr. sulphur, converts sulphuric into sulphurous acid. Several metals at an elevated temperature decompose this acid, with evolution of sulphurous acid gas, oxidizement of the metal, and combination of the oxide, with the undecomposed portion of the acid.*

The sulphuric acid is of very extensive use in the art of chemistry, as well as in metallurgy, bleaching, and some of the processes for dyeing; in medicine it is given as a tonic, stimulant, and lithontriptic, and sometimes used externally as a caustic.

The combinations of this acid with the various bases are called sulphates, and most of them have long been known by various names. With barytes it is found native and nearly pure in various forms, in coarse powder, rounded masses, stalactites, and regular crystallizations, which are in some lamellar, in others needly, in others prismatic or pyramidal. The cawks of our country and the *Bolognian stone* are merely native sulphates of barytes. Their colour varies considerably as well as their figure, but their specific gravity is great, that of a very impure kind being 3.89, and the pure sorts varying from 4 to 4.865; hence it has been distinguished by the names of *marmor metallicum* and *ponderous spar*.

* It consists, according to Dr. Wollaston, of 5 parts of dry acid, and 9.75 of barytes; and by Professor Berzelius's last estimate, of 5 of acid and 9.573 barytes.*

This salt, though deleterious, is less so than the carbonate of barytes, and is more economical for preparing the muriate for medicinal purposes. It requires 43.000 parts of water to dissolve it at 60°.

Sulphate of strontian has a considerable resemblance to that of barytes in its properties. It is found native in considerable quantities at Aust Passage and other places in the neighbourhood of Bristol. It requires 3840 parts of boiling water to dissolve it.

* Its composition is 5 acid + 6.5 base.*

The sulphate of potash, *vitriolated kali* of the London college, formerly *vitriolated tartar*, *sal de duobus*, and *arcanum duplicatum*, crystallizes in hexaëdral prisms, terminated by hexagonal pyramids, but susceptible of variations. Its crystallization by quick cooling is confused. Its taste is bitter, acrid, and a little saline. It is soluble in 5 parts of boiling water, and 16 parts at 60°. In the fire it decrepitates, and is fusible by a strong heat. It is decomposable by charcoal at a high temperature. It may be prepared by direct mixture of its component parts; but the usual and cheapest mode is to neutralize the acidulous sulphate left after distilling nitric acid, the *sal enixum* of the old chemists, by the addition of carbonate of potash. The *sal polychrest* of old dispensatories, made by deflagrating sulphur and nitre in a crucible, was a compound of the sulphate and sulphite of potash. The acidulous sulphate is sometimes employed as a flux, and likewise in the manufacture of alum. In medicine the neutral salt is sometimes used as a deobstruent, and in large doses as a mild cathartic; dissolves in a considerable portion of water, and taken daily in such quantity as to be gently aperient, it has been found serviceable in cutaneous affections, and is sold in London for this purpose as a nostrum; and certainly it deserves to be distinguished from the generality of quack medicines, very few indeed of which can be taken without imminent hazard.

* It consists of 5 acid + 5.95 base; but there is a compound of the same constituents, in the proportion of 10 acid + 5.95 potash, called the bisulphate.*

The sulphate of soda is the *vitriolated natron* of the college, the well known *Glauber's salt*, or *sal mirabile*. It is commonly prepared from the residuum left after distilling muriatic acid, the superfluous acid of which may be saturated by the addition of soda, or precipitated by lime; and is likewise obtained in the manufacture of the muriate of ammonia. (See AMMONIA). Scherer mentions another mode by Mr. Funcke, which is, making 8 parts of calcined sulphate of lime, 5 of clay, and 5 of common salt, into a paste with water; burning this in a kiln; and then powdering, lixiviating, and crystallizing. It exists in large quantities under the surface of the earth in some countries, as Persia, Bohemia, and Switzerland; is found mixed with other substances in mineral springs
and sea water; and sometimes effl
on walls. Sulphate of soda is bit
saline to the taste. It is soluble
parts of cold water, and 0.8 at a
heat; it crystallizes in hexagonal
bevelled at the extremities, son
grooved longitudinally, and of ve
size, when the quantity is great
effloresce completely into a whi
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dried sulphate of soda, produce
solid, pale, yellow glass.

* It is composed of 5 acid +
+ 11.25 water in crystals; whe
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crystallization. In this state it
tive in Tyrol, crystallized in
parallelopipeds, or octaëdral
prisms, and is called *anhydrous*
lime. Both the natural and art
drous sulphate consists of 56
43.6 acid, according to Mr.
The calcined sulphate is muc
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mental figures; as one of t
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If sulphate of ammonia and sulphate of magnesia be added together in solution, they combine into a triple salt of an octaëdral figure, but varying much; less soluble than either of its component parts; unalterable in the air; undergoing on the fire the watery fusion; after which it is decomposed, part of the ammonia flying off, and the remainder subliming with an excess of acid. It contains, according to Fourcroy, 68 sulphate of magnesia, and 32 sulphate of ammonia.

Sulphate of glucina crystallizes with difficulty, its solution readily acquiring and retaining a sirupy consistence; its taste is sweet, and slightly astringent; it is not alterable in the air; a strong heat expels its acid, and leaves the earth pure; heated with charcoal it forms a sulphuret; infusion of galls forms a yellowish white precipitate with its solution.

Yttria is readily dissolved by sulphuric acid; and as the solution goes on, the sulphate crystallizes in small brilliant grains, which have a sweetish taste, but less so than sulphate of glucina, and are of a light amethyst red colour. They require 30 parts of cold water to dissolve them, and give up their acid when exposed to a high temperature. They are decomposed by oxalic acid, prussiate of potash, infusion of galls, and phosphate of soda.

Sulphate of alumina in its pure state is but recently known, and it was first attentively examined by Vauquelin. It may be made by dissolving pure alumina in pure sulphuric acid, heating them for some time, evaporating the solution to dryness, drying the residuum with a pretty strong heat, redissolving it, and crystallizing. Its crystals are soft, foliaceous, shining, and pearly; but these are not easily obtained without cautious evaporation and refrigeration. They have an astringent taste; are little alterable in the air; are pretty soluble, particularly in hot water; give out their acid on exposure to a high temperature; are decomposable by combustible substances, though not readily; and do not form a pyrophorus like alum.

If the evaporation and desiccation directed above be omitted, the alumina will remain supersaturated with acid, as may be known by its taste, and by its reddening vegetable blue. This is still more difficult to crystallize than the neutral salt, and frequently thickens into a gelatinous mass.

A compound of acidulous sulphate of alumina with potash or ammonia has long been known by the name of Alum. See Alumina.

If this acidulous sulphate or alum be dissolved in water, and boiled with pure alumina, the alumina will become saturated with its base, and fall down an insipid white powder. This salt is completely insoluble, and is not deprived of its acid by heat but at a very high temperature. It may be decomposed by long boiling with the alkaline or earth bases; and several acids convert it into common alum, but slowly.

Sulphate of zircon may be prepared by adding sulphuric acid to the earth recently precipitated, and not yet dry. It is sometimes in small needles, but commonly pulverulent; very friable; insipid; insoluble in water, unless it contain some acid; and easily decomposed by heat.

Acid (Sulphurous.) It has already been observed, that sulphur burned at a low temperature absorbs less oxygen than it does when exposed to greater heat, and is consequently acidified in a slighter degree, so as to form sulphurous acid. This in the ordinary state of the atmosphere is a gas; but on reducing its temperature very low by artificial cold, and exposing it to strong compression, it becomes a liquid. To obtain it in the liquid state, however, for practical purposes, it is received into water, by which it is absorbed.

As the acid obtained by burning sulphur in this way is commonly mixed with more or less sulphuric acid, when sulphurous acid is wanted, it is commonly made by abstracting part of the oxygen from sulphuric acid by means of some combustible substance. Mercury or tin is usually preferred. For the purposes of manufactures, however, chopped straw or saw-dust may be employed. If one part of mercury and two of concentrated sulphuric acid be put into a glass retort with a long neck, and heat applied till an effervescence is produced, the sulphurous acid will arise in the form of gas, and may be collected over quicksilver, or received into water, which at the temperature of 61° will absorb 33 times its bulk, or nearly an eleventh of its weight.

Water thus saturated is intensely acid to the taste, and has the smell of sulphur burning slowly. It destroys most vegetable colours, but the blues are reddened by it previous to their being discharged. A pleasing instance of its effect on colours may be exhibited by holding a red rose over the blue flame of a common match, by which the colour will be discharged wherever the sulphurous acid comes into contact with it, so as to render it beautifully variegated, or entirely white. If it be then dipped into water, the redness after a time will be restored.

* The specific gravity of sulphurous acid gas, as given by MM. Thenard and Gay-Lussac, is 2.2553, but by Sir H. Davy is 2.2295, and hence 100 cubic inches weigh 68 grains; but its sp. gr. most probably should be estimated at 2.222, and the weight of 100 cubic inches will become 67.777. Its constituents by volume are one of oxygen, and one of vapour of sulphur; each having a sp. gr. of 1.111, condensed so that both volumes occupy only one. Or in popular language, sulphurous acid may be said to be a solution of sulphur in oxygen, which doubles the weight of this gas, without augmenting its bulk. It obviously, therefore, consists by weight of equal quantities of the two constituents. Its equivalent will either be 2 oxygen + 2 sulphur = 4; or 1 oxygen + 1 sulphur = 2. Now the analysis of sulphite of barytes by Berzelius gives 209.22 base to 86.53 acid; which being reduced, presents for the prime equivalent of sulphurous acid, the number 4. Hydrogen and carbon readily decompose sulphurous acid at a red heat, and even under it. Mr. Higgins discovered, that liquid sulphurous acid dissolves iron, without the evolution of any gas The peroxides of lead and manganese furnish oxygen to convert it into sulphuric acid, which forms a sulphate, with the resulting metallic protoxide.*

Sulphurous acid is used in bleaching, particularly for silks. It likewise discharges vegetable stains, and iron-moulds from linen.

In combination with the salifiable bases, it forms sulphites, which differ from the sulphates in their properties The alkaline sulphites are more soluble than the sulphates, the earthy less. They are converted into sulphates by an addition of oxygen, which they acquire even by exposure to the air. The sulphite of lime is the slowest to undergo this change. A strong heat either expels their acid entirely, or converts them into sulphates. They have all a sharp, disagreeable, sulphurous taste. The best mode of obtaining them is by receiving the sulphurous acid gas into water, holding the base, or its carbonate, in solution, or diffused in it in fine powder. None of them has yet been applied to any use.

* Acid (Hyposulphurous.) In the 85th volume of the Annales de Chimie, M. Gay-Lussac describes permanent crystallizable salts having lime and strontites for their base, combined with an acid of sulphur, in which the proportion of oxygen is less than in sulphurous acid; but this acid he does not seem to have examined in a separate state. Those salts were procured by exposing solutions of the sulphurets of the earths to the air, when sulphur and carbonate of lime precipitated. When the filtered liquid is then evaporated, and cooled, colourless crystals form. The calcareous are prismatic needles, and those with strontites are rhomboidal. He called these new compounds sulphuretted sul-

phites. Those of potash and soda he also formed, by heating their sulphites with sulphur; when, a quantity of sulphurous acid was disengaged, and neutral salts were formed. M. Gay-Lussac farther informs us, that boiling a solution of a sulphite with sulphur, determines the formation of the sulphuretted sulphite, or hyposulphite; and that iron, zinc, and manganese, treated with liquid sulphurous acid, yield sulphuretted sulphites; from which it follows, that a portion of the sulphurous acid is decomposed by the metal, and that the resulting oxide combines with the other portion of the sulphurous acid and the liberated sulphur. The hyposulphites are more permanent than the sulphites; they do not readily pass by the action of the air into the state of sulphate; and though decomposable at a high heat, they resist the action of fire longer than the sulphites. They are decomposed in solution by the sulphuric, muriatic, fluoric, phosphoric, and arsenic acids; sulphurous acid is evolved, sulphur is precipitated, and a *new* salt is formed. Such is the account given of these by M. Gay-Lussac, and copied into the second volume of the Traité de Chimie of M. Thenard, published in 1814.

No additional information was communicated to the world on this subject till January 1819, when an ingenious paper on the hyposulphites appeared in the Edinburgh Philosophical Journal, followed soon by two others in the same periodical work, by Mr. Herschel.

In order to obtain hyposulphurous acid, Mr. Herschel mixed a dilute solution of hyposulphite of strontites with a slight excess of dilute sulphuric acid, and after agitation poured the mixture on three filters. The first was received into a solution of carbonate of potash, from which it expelled carbonic acid gas. The second portion being received successively into nitrates of silver and mercury, precipitated the metals copiously in the state of sulphurets, but produced no effect on solutions of copper, iron, or zinc. The third, being tasted, was acid, astringent and bitter. When fresh filtered it was clear, but it became milky on standing, depositing sulphur, and colouring sulphurous acid. A moderate exposure to air, or a gentle heat, caused its entire decomposition.

The habitudes of oxide of silver in union with this acid are very peculiar. Hyposulphite of soda being poured on newly precipitated oxide of silver, hyposulphite of silver was formed, and caustic soda eliminated; the only instance, says Mr. Herschel, yet known of the direct displacement of a fixed alkali by a metallic oxide, *via humida*. On the other hand, hyposulphurous acid newly disengaged from the hyposulphite of barytes, by dilute sulphuric acid, readily dissolved, and decomposed muriate of silver, forming a sweet solution, from which alcohol separated the metal in the state of hyposulphite, "Thus the affinity between this acid and base, *unassisted by any double decomposition*, is such as to form an exception to all the ordinary rules of chemical union." This acid has a remarkable tendency to form double salts with the oxides of silver and alkaline bases. The hyposulphite of silver and soda has an intensely sweet taste. When hyposulphite of ammonia is poured on muriate of silver, it dissolves it; and if into the saturated solution, alcohol be poured, a white salt is precipitated, which must be forcibly squeezed between blotting paper and dried *in vacuo*. It is very soluble in water. Its sweetness is unmixed with any other flavour, and so intense as to cause pain in the throat. One grain of the salt communicates a perceptible sweetness to 32,000 grains of water. If the alcoholic liquid be evaporated, thin lengthened hexangular plates are sometimes formed, which are not altered by keeping, and consist of the same principles.

The best way of obtaining the alkaline hyposulphites is to pass a current of sulphurous acid gas through a *lixivium*, formed by boiling a watery solution of alkali, or alkaline earth, along with sulphur. The whole of the sulphurous acid is converted into the hyposulphite, and pure sulphur, unmixed with any sulphite, is precipitated, while the hyposulphite remains in solution.

Mr. Herschel, from his experiments on the hyposulphite of lime, has deduced the prime equivalent of hyposulphurous acid, to be 5.925. He found that 100 parts crystallized hyposulphite of lime, were equivalent to 121.77 hyposulphite of lead, and yielded of carbonate of lime, by carbonate of ammonia, a quantity equivalent to 21.75 gr. of lime. Therefore the theory of equivalent ratios gives us this rule:

As 21.75 gr. lime are to its prime equivalent 3.56, so are 121.77 gr. of hyposulphite of lead, to *its* prime equivalent. In numbers 21.75 : 3.56 : : 121.77 : 19.93. From this number, if we deduct the prime of the oxide of lead = 14, the remainder 5.93 will be the double prime of hyposulphurous acid. Now this number does not materially differ from 6. Hence we see that the hyposulphites, for their neutral condition, require of this feeble acid 2 prime proportions. One prime proportion of it is obviously made up of 1 prime of sulphur = 2, + 1 oxygen = 1; and the acid equivalent is = 3. The crystallized hyposulphite of lime is composed of 6. acid + 3.56 lime + 6.75 water, being 6 primes of the last constituent.

It ought to be stated, that when a solution of a hyposulphite is boiled down to a certain degree of concentration, it begins to be rapidly decomposed, with the deposition of sulphur and sulphite of lime. To obtain the salt in crystals, the solution must be evaporated at a temperature not exceeding 140° Fahr. If it be then filtered while hot, it will yield on cooling, large and exceedingly beautiful crystals, which assume a great variety of complicated forms. They are soluble in nearly their own weight of water at 37° Fahr. and the temperature of the solution falls to 31°. The specific gravity of their saturated solution at 60° is 1.300; and when it is 1.114, the liquid contains one-fifth of its weight. The crystals are permanent in the air.

Hyposulphites of potash and soda yield deliquescent crystals of a bitter taste, and both of them dissolve muriate of silver. The ammoniacal salt is not easily procured in regular crystals. Its taste is pungent and disagreeable. The barytic hyposulphite is insoluble; the strontitic is soluble and crystallizable. Like the other hyposulphites it dissolves silver; and while its own taste is purely bitter, it produces a sweet compound with muriate of silver, which alcohol throws down in a sirupy form. Hyposulphite of magnesia is a bitter tasted, soluble, crystallizable, and non-deliquescent salt. All the hyposulphites burn with a sulphurous flame. The sweetness of liquid hyposulphite of soda, combined with muriate of silver, surpasses honey in intensity, diffusing itself over the whole mouth and fauces without any disagreeable or metallic flavour. A coil of zinc wire speedily separates the silver in a metallic state, thus affording a ready analysis of muriate of silver. Muriate of lead is also soluble in the hyposulphites, but less readily.*

* Acid (Hyposulphuric). MM. Gay-Lussac and Welther have recently announced the discovery of a new acid combination of sulphur and oxygen, intermediate between sulphurous and sulphuric acids, to which they have given the name of hyposulphuric acid. It is obtained by passing a current of sulphurous acid gas over the black oxide of manganese. A combination takes place; the excess of the oxide of manganese is separated by dissolving the hyposulphate of manganese in water. Caustic barytes precipitates the manganese, and forms with the new acid a very soluble salt, which, freed from excess of barytes by a current of carbonic acid, crystallizes regularly, like the nitrate or muriate of barytes. Hyposulphate of barytes being thus obtained, sulphuric acid is cautiously added to the solution, which throws down the barytes, and leaves the hyposulphuric acid in the water. This acid bears considerable concentration under the receiver of the air-pump. It consists of five parts of oxygen to four of sulphur. The greater number of the hyposulphates, both earthy and metallic are soluble and crystallize; those of barytes and lime are unalterable in the air. Suberic acid and chlorine do not decompose the barytic salt The barytic salt in crystals, consists of barytes 9.7 + hyposulphuric acid 9.00 + water 2.25 = 20.95.

The following table exhibits the composition of the different acid compounds of sulphur and oxygen:

Hyposulphurous acid	20 sul.	+ 10 oxygen
Sulphurous acid	10	+ 10
Hyposulphuric acid	8	+ 10
Sulphuric acid	$2\frac{2}{3}$	+ 10

Or if we prefer to consider the quantity of sulphur in each acid as = 2, the oxygen combines with it in the following proportions:—1; 2; 2.5; 3.

Hyposulphuric acid is distinguished by the following properties:

1st, It is decomposed by heat into sulphurous and sulphuric acids.

2d, It forms soluble salts with barytes, strontites, lime, lead, and silver.

3d, The hyposulphates are all soluble.

4th, They yield sulphurous acid when their solutions are mixed with acids, only if the mixture becomes hot of itself, or be artificially heated.

5th, They disengage a great deal of sulphurous acid at a high temperature, and are converted into neutral sulphates.

Before quitting the acids of sulphur, it deserves to be mentioned, that Dr. Gulès of Paris, has, by means of a chest or case, called Boëte Fumigatoire, applied the vapour of burning sulphur, or sulphurous acid gas, mixed with air, to the surface of the body, as an air bath, with great advantage, in many chronic diseases of the skin, the joints, the glands, and the lymphatic system.*

Acid (Tartaric). The casks in which some kinds of wine are kept become incrusted with a hard substance, tinged with the colouring matter of the wine, and otherwise impure, which has long been known by the name of *argal*, or tartar, and distinguished into red and white according to its colour. This being purified by solution, filtration, and crystallization, was termed *cream* or *crystals of tartar*. It was afterwards discovered, that it consisted of a peculiar acid combined with potash; and the supposition that it was formed during the fermentation of the wine, was disproved by Boerhaave, Neumann, and others, who showed that it existed ready formed in the juice of the grape. It has likewise been found in other fruits, particularly before they are too ripe; and in the tamarind, sumac, balm, carduus benedictus, and the roots of rest-harrow, germander, and sage. The separation of tartaric acid from this acidulous salt, is the first discovery of Scheele that is known. He saturated the superfluous acid by adding chalk to a solution of the supertartrate in boiling water as long as any effervescence ensued, and expelled the acid from the precipitated tartrate of lime by means of the sulphuric. Or four parts of tartar may be boiled in twenty or twenty-four of water, and one part of sulphuric acid added gradually. By continuing the boiling the sulphate of potash will fall down. When the liquor is reduced to one-half, it is to be filtered, and if any more sulphate be deposited by continuing the boiling, the filtering must be repeated. When no more is thrown down, the liquor is to be evaporated to the consistence of a sirup, and thus crystals of tartaric acid, equal to half the weight of the tartar employed, will be obtained.

The tartaric acid may be procured in needly or laminated crystals, by evaporating a solution of it. Its taste is very acid and agreeable, so that it may supply the place of lemon-juice. It is very soluble in water. Burnt in an open fire, it leaves a coaly residuum; in close vessels it gives out carbonic acid and carburetted hydrogen gas. By distilling nitric acid off the crystals they may be converted into oxalic acid, and the nitric acid passes to the state of nitrous.

* To extract the whole acid from tartar, M. Thenard recommends, after saturating the redundant acid with chalk, to add muriate of lime to the supernatant neutral tartrate, by which means it is completely decomposed. The insoluble tartrate of lime being washed with abundance of water, is then to be treated with three-fifths of its weight of strong sulphuric acid, diluted previously with five parts of water. But Fourcroy's process as improved by Vauquelin, seems still better. Tartar is treated with quicklime and boiling water in the proportion, by the theory of equivalents, of 100 of tartar to 30 of dry lime, or 40 of the slaked. A caustic magma is obtained, which must be evaporated to dryness, and gently heated. On digesting this in water, a solution of caustic potash is obtained, while tartrate of lime remains; from which the acid may be separated by the equivalent quantity of oil of vitriol.

According to Berzelius, tartaric acid is a compound of 3.807 hydrogen + 35.980 carbon + 60.213 oxygen = 100; to which result he shows that of M. Gay-Lussac and Thenard to correspond, when allowance is made for a certain portion of water, which they had omitted to estimate. The analysis of tartrate of lead, gives 8.384 for the acid prime equivalent; and it may be made up of

3 hydrogen	= 0.375	4.48
4 carbon	= 3.000	35.82
5 oxygen	= 5.000	59.70
	8.375	100.00

The crystallized acid is a compound of 8.375 acid + 1.125 water = 9.5; or in 100 parts 88.15 acid + 11.85 water.

The tartrates in their decomposition by fire, comport themselves like all the other vegetable salts, except that those with excess of acid yield the smell of *caromel* when heated, and afford a certain quantity of the pyrotartaric acid. All the soluble neutral tartrates form with tartaric acid, bitartrates of sparing solubility; while all the insoluble tartrates may be dissolved in an excess of their acid. Hence, by pouring gradually an excess of acid into barytes, strontites and lime-waters, the precipitates formed at first cannot fail to disappear; while those obtained by an excess of the same acid, added to concentrated solutions of potash, soda, or ammonia, and the neutral tartrates of these bases, as well as of magnesia and copper, must be permanent. The first are always flocculent; the second always crystalline; that of copper alone, is in a greenish-white powder. It likewise follows, that the greater number of acids ought to disturb the solutions of the alkaline neutral tartrates, because they transform these salts into bitartrates; and on the contrary, they ought to effect the solution of the neutral insoluble tartrates, which indeed always happens, unless the acid cannot dissolve the base of the tartrate. The order of apparent affinities of tartaric acid are, lime, barytes, strontites, potash, soda, ammonia, and magnesia.

The tartrates of potash, soda, and ammonia, are not only susceptible of combining together, but also with the other tartrates, so as to form double or triple salts. We may thus easily conceive why the tartrates of potash, soda, and ammonia, do not disturb the solutions of iron and manganese; and on the other hand disturb the solutions of the salts of barytes, strontites, lime, and lead. In the first case, double salts are formed, however small a quantity of tartrate shall have been employed; in the second, no double salt is formed unless the tartrate be added in very great excess.*

The tartrates of lime and barytes are white, pulverulent, and insoluble.

Tartrate of strontian, formed by the double decomposition of muriate of strontian and tartrate of potash, according to Vauquelin, is soluble, crystallizable, and consists of 52.88 strontian and 47.12 acid.

That of magnesia forms a gelatinous or gummy mass.

Tartrate of potash, the *tartarized kali* of the London college, and *vegetable salt* of some, formerly called *soluble tartar*, because much more so than the supertartrate, crystallizes in oblong squares, bevelled at the extremities. It has a bitterish taste, and is decomposed by heat, as its solution is even by standing some time. It is used as a mild purgative.

The supertartrate of potash, already mentioned at the beginning of this article, is much used as a cooling and gently opening medicine, as well as in several chemical and pharmaceutical preparations. Dissolved in water, with the addition of a little sugar, and a slice or two of lemon-peel, it forms an agreeable cooling drink by the name of *imperial;* and if an infusion of green balm be used instead of water, it makes one of the pleasantest liquors of the kind with which we are acquainted. Mixed with an equal weight of nitre, and projected into a red-hot crucible, it detonates, and forms the *white flux;* treated in the same way with half its weight of nitre, it forms the *black flux;* and simply mixed with nitre in various proportions, it is called *raw flux*. It is likewise used in dyeing, in hat-making, in gilding, and in other arts.

* The blanching of the crude tartar is aided by boiling its solution with $\frac{1}{20}$ of pipe clay.

According to the analysis of Berzelius, it consists of 70.45 acid + 24.8 potash + 4.75 water = 100; or

2	primes acid,	=	16.75	70.30
1	potash,	=	5.95	24.95
1	water,	=	1.125	4.75
			23.825	100.00

60 parts of water dissolve 4 of bitartrate at a boiling heat; and only 1 at 60° Fahr. It is quite insoluble in alcohol. It becomes very soluble in water, by adding to it one-fifth of its weight of borax; or even by the addition of boracic acid. It appears by Berzelius, that neutral tartrate of potash, dried in the sun, differs from the bitartrate, in containing no water of crystallization. He states it to be a compound of 58.69 acid + 41.31 potash = 100; which afford 155.7 tartrate of lead. Now, 8.375 : 5.95 : : 58.5 : 41.5; which are the equivalent proportions.

On considering the great solvent property of cream of tartar, and that it is even capable of dissolving various oxides, which are insoluble in tartaric acid, as the protoxide of antimony, M. Gay-Lussac has recommended it as a useful agent in chemical analysis. He thinks that in many cases it acts the part of a single acid. According to this view, tartar emetic would be a compound of the *cream-tartar* acid, and protoxide of antimony. Cream of tartar generally contains from 3 to 5 per cent of tartrate of lime, which are in a great measure separated when 3 parts of tartar are boiled with 1 of borax for a few minutes in a sufficient quantity of water. The soluble cream of tartar which is obtained by this process is deliquescent; it dissolves in its own weight of water at 54.5°, and in half its weight of boiling water. Its solution is very imperfectly decomposed by the sulphuric, nitric, and muriatic acids. 4 parts of tartar and 1 of boracic acid form a permanent saline compound, very soluble in water. Alum also increases the solubility of tartar.*

By saturating the superfluous acid in this supertartrate with soda, a triple salt is formed, which crystallizes in large regular prisms of eight nearly equal sides, of a bitter taste, efflorescent, and soluble in about five parts of water. It consists, according to Vauquelin, of 54 parts tartrate of potash and 46 tartrate of soda, and was once in much repute as a purgative, by the name of *Rochelle salt*, or *sel de Seignette*.

The tartrate of soda is much less soluble than this triple salt, and crystallizes in slender needles or thin plates.

The tartrate of ammonia is a very soluble, bitter salt, and crystallizes easily. Its solution is spontaneously decomposable.

This too forms with tartrate of potash a triple salt, the solution of which yields, by cooling, fine pyramidal or prismatic efflorescent crystals. Though both the neutral salts that compose it are bitter, this is not, but has a cooling taste.

Acid (Tungstous). What has been thus called appears to be an oxide of Tungsten.

* Acid (Tungstic) has been found only in two minerals; one of which formerly called tungsten, is a tungstate of lime, and is very rare; the other more common, is composed of tungstic acid, oxide of iron, and a little oxide of manganese. The acid is separated from the latter in the following way. The wolfram cleared from its siliceous *gangue*, and pulverized, is heated in a matrass with five or six times its weight of muriatic acid, for half an hour. The oxides of iron and manganese being thus dissolved, we obtain the tungstic acid under the form of a yellow powder. After washing it repeatedly with water, it is then digested in an excess of liquid ammonia, heated, which dissolves it completely. The liquor is filtered and evaporated to dryness in a capsule. The dry residue being ignited, the ammonia flies off, and pure tungstic acid remains. If the whole of the wolfram has not been decomposed in this operation, it must be subjected to the muriatic acid again.

It is tasteless, and does not affect vegetable colours. The tungstates of the alkalis and magnesia are soluble and crystallizable, the other earthy ones are insoluble, as well as those of the metallic oxides. The acid is composed of 100 parts metallic tungsten, and 25 or 26.4 oxygen.*

Acid (Uric). The same with Lithic Acid; which see.

Acid (Zoonic). In the liquid procured by distillation from animal substances, which had been supposed to contain only carbonate of ammonia and an oil, Berthollet imagined he had discovered a peculiar acid, to which he gave the name of zoonic. Thenard, however, has demonstrated that it is merely acetic acid combined with an animal matter.

* Acid (Zumic). An acid called by M. Braconnot, Nanceic, in honour of the town of Nancy, where he lives. He discovered it in many acescent vegetable substances; in sour rice; in putrefied juice of beet-root; in sour decoction of carrots, peas, &c. He imagines that this acid is generated at the same time as vinegar in organic substances, when they become sour. It is without colour, does not crystallize, and has a very acid taste

He concentrates the soured juice of the beet-root till it become almost solid, digests it with alcohol, and evaporates the alcoholic solution to the consistence of sirup. He dilutes this with water, and throws into it carbonate of zinc till it be saturated. He passes the liquid through a filter, and evaporates till a pellicle appear. The combination of the new acid with oxide of zinc crystallizes. After a second crystallization, he dissolves it in water, pours in an excess of water of barytes, decomposes by sulphuric acid the barytic salt formed, separates the deposite by a filter, and obtains, by evaporation, the new acid, pure.

It forms with alumina a salt resembling gum, and with magnesia one unalterable in the air, in little granular crystals, soluble in 25 parts of water at 66° Fahr; with potash and soda it forms uncrystallizable salts, deliquescent and soluble in alcohol; with lime and strontites, soluble granular salts; with barytes, an uncrystallizable nondeliquescent salt having the aspect of gum; with white oxide of manganese, a salt which crystallizes in tetrahedral prisms, soluble in 12 parts of water at 60°; with oxide of zinc, a salt crystallizing in square prisms, terminated by summits obliquely truncated, soluble in 50 parts of water at 66°; with iron, a salt crystallizing in slender four-sided needles, of sparing solubility and not changing in the air; with red oxide of iron, a white noncrystallizing salt; with oxide of tin, a salt crystallizing in wedge-form octahedrons; with oxide of lead an uncrystallizable salt, not deliquescent, and resembling a gum; with black oxide of mercury, a very soluble salt, which crystallizes in needles.*

Acidifiable. Capable of being converted into an acid by an acidifyng principle. (See Acid). Substances possessing this property are called *radicals*, or *acidifiable bases*.

Acidule. A term applied by the French chemists to those salts, in which the base is combined with such an excess of acid, that they manifestly exhibit acid properties; such as the supertartrate of potash.

* Aconita. A poisonous vegetable principle, probably alkaline, recently extracted from the *Aconitum napellus*, or Wolfsbane, by M. Brandes. The details of the analysis have not reached this country.*

* Actinolite. *Strahlstein* of Werner. *Amphibole Actinote hexaèdre* of Hauy. There are three varieties of this mineral: the *crystallized*, the *asbestous*, and the *glassy*.

1*st*, Crystallized actinolite. Colour leek green, and green of darker shades. It crystallizes in long oblique hexahedral prisms with irregular terminations. Crystals frequently striated lengthwise, sometimes acicular. Its lustre is shining. It is translucent. Occasionally it is found in silky fibres. Its sp. gr. varies from 3.0 to 3.3. Fracture usually radiated; sometimes it is foliated with an indistinct twofold cleavage. It scratches glass.

2*d*, Asbestous actinolite. Colours green, verging on gray and brown, and smalt-blue. Massive and in elastic capillary crystals, which are grouped in wedge-shaped, radiated or promiscuous masses. Internal lustre pearly. Melts before the blow-pipe into a dark glass. Fracture intermediate between fibrous and narrow radiated. Fragments wedge-shaped. Opaque. Soft. Tough but sectile. Sp. gr. 2.7 to 2.9.

3*d*, Glassy actinolite. Colours, mountain green, and emerald green. In thin six sided needle-form crystals. Has cross rents. Sp. gr. from 3.0 to 3.2. The composition of actinolite is very differently stated by different analysts. Laugier's results with glassy actinolite are the following, and they approximate to those of Vauquelin on asbestous actinolite; silica 50, lime 9.75, magnesia 19.25, oxide of iron 11, alumina 0.75, oxide of maganese 0.5, oxide of chromium 3, potash 0.5, moisture 5, loss 0.25. 28.2 of alumina and 3.84 of tungstic acid were found in 100 parts of asbestous actinolite from Cornwall, analyzed by Dr. Thomson. Actinolite is found chiefly in primitive districts, with a magnesian basis. It accompanies talc, and some micaceous rocks. Its principal localities are Zillerthal, in the Tyrol; Mont St. Gothard; near Saltzburg, in Saxony; in Norway and in Piedmont. In Great Britain, it is found in Cornwall and Wales; and in Glen Elg, the isles of Lewis and Sky. It is never found in secondary mountains.*

Adamant. See **Diamond.**

Adamantine Spar. This stone, which comes to us from the peninsula of Hither India, and also from China, has not engaged the attention of the chemical world till within a few years past. It is remarkable for its extreme hardness, which approaches to that of the diamond, and by virtue of which property it is used for polishing gems.

Two varieties of this stone are known in Europe. The first comes from China. It is crystallized, in six-sided prisms, without pyramids, the length of which varies from half an inch to an inch, and their thickness is about three quarters of an inch. Its colour is gray of different shades. The larger pieces are opaque; but thin pieces and the edges of the prisms are transparent. Its fracture is brilliant, and its texture spathose; which causes its surface to appear lightly striated. Its crystals are covered with a very fine and strongly adherent crust of plates of silvery mica, mixed with particles of red feldspar. A yellow superficial covering of sulphate of iron was observed upon one specimen.

This stone is so hard that it not only cuts glass as easily as a diamond, but likewise marks rock crystal and several other hard stones. Its specific gravity is 3.710.

Small crystalline grains of magnetical ferruginous calx are occasionally found in the adamantine spar of China, which may be separated by the magnet when the stone is pulverized.

The second variety, which comes from India, is called Corundum by the inhabitants of Bombay. It differs from the former by a white colour, a texture more evidently spathose, and lastly, because the grains of magnetical iron are smaller than in the former specimens, and are not interspersed through its substance, but only at its surface.

From its hardness it is extremely difficult to analyze. M. Chenevix, by repeatedly heating it red hot, and then plunging it into cold water, caused it to appear fissured in every direction. He then put it into a steel mortar, about three quarters of an inch in diameter, and three inches deep, to which a steel pestle was closely fitted. A few blows on the pestle caused it to crumble, and the fragments were then easily reduced to an impalpable powder by an agate pestle and mortar. This powder was fused in a crucible of platinum with twice its weight of calcined borax, and the glass was dissolved by boiling in muriatic acid about twelve hours. The precipitates from this solution being examined, a specimen from China was found to give from 100 parts, 86.50 of alumina, 5.25 of silex, 6.50 of iron: one from Ava, alumina 87, silex 6.5, iron 4.5: one from Malabar, alumina 86.5, silex 7, iron 4: one from the Carnatic, alumina 91, silex 5, iron 1.5.

The Rev. Mr. W. Gregor analyzed a specimen from Thibet, in the collection of Mr. Rashleigh, which gave him alumina 81.75, silex 12.125, oxide of titanium 4, water 0.937, but no iron.

This stone has been said to have been found in different parts of Europe, and near Philadelphia in America; but most, if not all of the specimens have proved not to be the adamantine spar. Lately, however, Prof. Pini has discovered a stone in Italy, the characters of which, as given by him, agree with those of the adamantine spar. See **Corundum.**

Adhesion. See **Cohesion.**

* **Adhesive Slate.** See **Slate.***

Adipocere. The attention of chemists has been much excited by the spontaneous conversion of animal matter into a substance considerably resembling spermaceti. The fact has long been well known, and is said to have been mentioned in the works of Lord Bacon, though I have not seen the passage. On the occasion of the removal of a very great number of human bodies from the ancient burying-place des Innocens at Paris, facts of this nature were observed in the most striking manner. Fourcroy may be called the scientific discoverer of this peculiar matter, as well as the saponaceous ammoniacal substance contained in bodies abandoned to spontaneous destruction in large masses. This chemist read a memoir on the subject in the year 1789 to the Royal Academy of Sciences, from which I shall abstract the general contents.

At the time of clearing the before mentioned burying-place, certain philosophers were specially charged to direct the precautions requisite for securing the health of the workmen. A new and singular object of research presented itself, which had been necessarily unknown to preceding chemists. It was impossible to foretell what might be the contents of a soil overloaded for successive ages with bodies resigned to the putrefactive process. This spot differed from common burying-grounds, where each individual object is surrounded by a portion of the soil. It was the burying-ground of a large district, wherein successive generations of the inhabitants had been deposited for upwards of three centuries. It could not be foreseen that the entire decomposition might be retarded for more than forty years; neither was there any reason to suspect that any remarkable difference would arise from the singularity of situation.

The remains of the human bodies immersed in this mass of putrescence were found in three different states, according to the time they had been buried, the place they occupied, and their relative situations with regard to each other. The most ancient were simply portions of bones, irregularly dispersed in the soil, which had been frequently disturbed. A second state, in certain bodies which had always been insulated, exhibited the skin, the muscles, tendons, and aponeuroses, dry, brittle, hard, more or less gray, and similar to what are called mummies in certain caverns where this change has been observed, as in the catacombs at Rome, and the vault of the Cordeliers at Toulouse.

The third and most singular state of these soft parts was observed in the bodies which filled the common graves or repositories. By this appellation are understood cavities of thirty feet in depth and twenty on each side, which were dug in the burying-ground of the Innocents, and were appropriated to contain the bodies of the poor; which were placed in very close rows, each in its proper wooden bier. The necessity for disposing a great number obliged the men charged with this employment to arrange them so near each other, that these cavities might be considered when filled as an entire mass of human bodies, separated only by two planks of about half an inch thick. Each cavity contained between one thousand and fifteen hundred. When one common grave of this magnitude was filled, a covering of about one foot deep of earth was laid upon it, and another excavation of the same sort was made at some distance. Each grave remained open about three years, which was the time required to fill it. According to the urgency of circumstances, the graves were again made on the same spot after an interval of time not less than fifteen years, nor more than thirty. Experience had taught the workmen, that this time was not sufficient for the entire destruction of the bodies, and had shown them the progressive changes which form the object of Mr. Fourcroy's memoir.

The first of these large graves opened in the presence of this chemist, had been closed for fifteen years. The coffins were in good preservation, but a little settled, and the wood (I suppose deal) had a yellow tinge. When the covers of several were taken off, the bodies were observed at the bottom, leaving a considerable distance between their surface and the cover, and flattened as if they had suffered a strong compression. The linen which had covered them was slightly adherent to the bodies; and, with the form of the different regions, exhibited, on removing the linen, nothing but irregular masses of a soft ductile matter of a gray white colour. These masses environed the bones on all sides, which had no solidity, but broke by any sudden pressure. The appearance of this matter, its obvious composition and its softness, resembled common white cheese; and the resemblance was more striking from the print which the threads of the linen had made upon its surface. This white substance yielded to the touch, and became soft when rubbed for a time between the fingers.

No very offensive smell was emitted from these bodies. The novelty and singularity of the spectacle, and the example of the grave-diggers, dispelled every idea either of disgust or apprehension. These men asserted that they never found this matter, by them called *gras* (fat), in bodies interred alone; but that the accumulated bodies of the common graves only were subject to this change. On a very attentive examination of a number of bodies passed to this state, M. Fourcroy remarked, that the conversion appeared in different stages of advancement, so that, in various bodies, the fibrous texture and colour, more or less red, were discernible within the fatty matter; that the masses covering the bones were entirely of the same nature, offering indistinctly in all the regions a gray substance, for the most part soft and ductile, sometimes dry, always easy to be separated in porous fragments, penetrated with cavities, and no longer exhibiting any traces of membranes, muscles, tendons, vessels, or nerves. On the first inspection of these white masses, it might have been concluded that they were simply the cellular tissue, the compartments and vesicles of which they very well represented.

By examining this substance in the different regions of the body, it was found that the skin is particularly disposed to this remarkable alteration. It was afterwards perceived that the ligaments and tendons no longer existed, or at least had lost their tenacity: so that the bones were entirely unsupported, and left to the action of their own weight. Whence their relative places were preserved in a certain degree by mere juxtaposition; the least effort being sufficient to separate them. The grave-diggers availed themselves of this circumstance in the removal of the bodies. For they rolled them up from head to feet, and by that means separated from each other the extremities of the bones, which had formerly been articulated. In all these bodies which were changed into the fatty matter, the abdominal cavity had disappeared. The teguments and muscles of this region being converted into the white matter, like the other soft parts, had subsided upon the vertebral column, and were so flattened as to leave no place for the viscera, and accordingly there was scarcely ever any trace observed in the almost obliterated cavity. This observation was for a long time matter of astonishment to the investigators. In vain did they seek in the greater number of bodies the place and substance of the stomach, the intestines, the bladder, and even the liver, the spleen, the kidneys, and the matrix in females. All these viscera were confounded together, and for the most part no traces of them were left. Sometimes only certain irregular masses were found, of the same nature as the white matter, of different bulks, from that of a nut to two or three inches in diameter, in the regions of the liver or of the spleen.

The thorax likewise offered an assemblage of facts no less singular and interesting. The external part of this cavity was flattened and compressed like the rest of the organs; the ribs, spontaneously luxated in their articulations with the vertebræ, were settled upon the dorsal column; their arched part left only a small space on each side between them and the vertebræ. The pleura, the mediastinum, the large vessels, the aspera arteria, and even the lungs and the heart, were no longer distinguishable; but for the most part had entirely disappeared, and in their place nothing was seen but some parcels of the fatty substance. In this case, the matter which was the product of decomposition of the viscera, charged with blood and various humours, differs from that of the surface of the body, and the long bones, in the red or brown colour possessed by the former. Sometimes the observers found in the thorax a mass irregularly rounded, of the same nature as the latter, which appeared to them to have arisen from the fat and fibrous substance of the heart. They supposed that this mass, not constantly found in all the subjects, owed its existence to a superabundance of fat in this viscus, where it was found. For the general observation presented itself, that in similar circumstances, the fat parts undergo this conversion more evidently than the others, and afford a larger quantity of the white matter.

The external region in females exhibited the glandular and adipose mass of the breasts converted into the fatty matter very white and very homogeneous.

The head was, as has already been remarked, environed with the fatty matter; the face was no longer distinguishable in the greatest number of subjects; the mouth disorganized exhibited neither tongue nor palate; and the jaws, luxated and more or less displaced, were environed with irregular layers of the white matter. Some pieces of the same matter usually occupied the place of the parts situated in the mouth; the cartilages of the nose participated in the general alteration of the skin; the orbits instead of eyes contained white masses; the ears were equally disorganized; and the hairy scalp, having undergone a similar alteration to that of the other organs, still retained the hair. M. Fourcroy remarks incidentally, that the hair appears to resist every alteration much longer than any other part of the body. The cranium constantly contained the brain contracted in bulk; blackish at the surface, and absolutely changed like the other organs. In a great number of subjects which were examined, this viscus was never found wanting, and it was always in the above-mentioned state; which proves that the substance of the brain is greatly disposed to be converted into the fat matter.

Such was the state of the bodies found in the burial-ground des innocens. Its modifications were also various. Its consistence in bodies lately changed, that is to say, from three to five years, was soft and very ductile; containing a great quantity of water. In other subjects converted into this matter for a long time, such as those which occupied the cavities which had been closed thirty or forty years, this matter is drier, more brittle, and in denser flakes. In several which were deposited in dry earth, various portions of the fatty matter had become semi-transparent. The aspect, the granulated texture, and brittleness of this dried matter, bore a considerable resemblance to wax.

The period of the formation of this substance had likewise an influence on its properties. In general, all that which had been formed for a long time was white, uniform, and contained no foreign substance, or fibrous remains; such, in particular, was that afforded by the skin of the extremities. On the contrary, in bodies recently changed, the fatty matter was neither so uniform nor so pure as in the former; but it was still found to contain portions of muscles, tendons, and ligaments, the texture of which, though already altered and changed in its colour, was still distinguishable. Accordingly, as the conversion was more or less advanced, these fibrous remains were more or less penetrated with the fatty matter, interposed as it were between the interstices of the fibres. This observation shows, that it is not merely the fat which is thus changed, as was natural enough to think at first sight. Other facts confirm this assertion. The skin, as has been remarked, becomes easily converted into very pure white matter, as does likewise the brain, neither of which has been considered by anatomists to be fat. It is true, nevertheless, that the unctuous parts, and bodies charged with fat, appear more easily and speedily to pass to the state under consideration. This was seen in the marrow, which occupied the cavities of the longer bones. And again, it is not to be supposed, but that the greater part of these bodies had been emaciated by the illness which terminated their lives; notwithstanding which, they were all absolutely turned into this fatty substance.

An experiment made by M. Poulletier de la Salle, and Fourcroy likewise evinced that a conversion does not take place in the fat alone. M. Poulletier had suspended in his laboratory a small piece of the human liver, to observe what would arise to it by the contact of the air. It partly putrefied, without, however, emitting any very noisome smell. Larvæ of the dermestes and bruchus attacked and penetrated it in various directions; at last it became dry, and after more than ten years' suspension, it was converted into a white friable substance resembling dried agaric, which might have been taken for an earthy substance. In this state it had no perceptible smell. M. Poulletier was desirous of knowing the state of this animal matter, and experiment soon convinced him and M. F. that it was very far from being in the state of an earth. It melted by heat, and exhaled in the form of vapour, which had the smell of a very fetid fat; spirit of wine separated a concrescible oil, which appeared to possess all the properties of spermaceti. Each of the three alkalis converted it into soap, and in a word it exhibited all the properties of the fatty matter of the burial-ground of the Innocents exposed for several months to the air. Here then was a glandular organ, which in the midst of the atmosphere had undergone a change similar to that of the bodies in the burying-place; and this fact sufficiently shows, that an animal substance which is very far from being of the nature of grease, may be totally converted into this fatty substance.

Among the modifications of this remarkable substance in the burying-ground before mentioned, it was observed that the dry, friable, and brittle matter, was most commonly found near the surface of the earth, and the soft ductile matter at a greater depth. M. Fourcroy remarks, that this dry matter did not differ from the other merely in containing less water, but likewise by the volatilization of one of its principles.

The grave-diggers assert, that near three years are required to convert a body into this fatty substance. But Dr. Gibbes of Oxford found, that lean beef secured in a running stream was converted into this fatty matter at the end of a month. He judges from facts, that running water is most favourable to this process. He took three lean pieces of mutton, and poured on each a quantity of the three common mineral acids. At the end of three days, each was much changed: that in the nitric acid was very soft, and converted into the fatty matter; that in the muriatic acid was not in that time so much altered; the sulphuric acid had turned the other black. M. Lavoisier thinks that this process may hereafter prove of great use in society. It is not easy to point out what animal substance, or what situation, might be the best adapted for an undertaking of this kind. M. L. points out fecal matters; but I have not heard of any conversion having taken place in these animal remains, similar to that of the foregoing.

The result of M. Fourcroy's inquiries into the ordinary changes of bodies recently deposited in the earth, was not very extensive. The grave-diggers informed him, that these bodies interred do not perceptibly change colour for the first seven or eight days; that the putrid process disengages elastic fluid, which inflates the abdomen, and at length bursts it; that this event instantly causes vertigo, faintness, and nausea in such persons as unfortunately are within a certain distance of the scene where it takes place; but that when the object of its action is nearer, a sudden privation of sense, and frequently death, is the consequence. These men are taught by experience, that no immediate danger is to be feared from the disgusting business they are engaged in, excepting at this period, which they regard with the utmost terror. They resisted every inducement and persuasion which these philosophers made use of, to prevail on them to assist their researches into the nature of this active and pernicious vapour. M. Fourcroy takes occasion from these facts, as well as from the pallid and unwholesome appearance of the grave-diggers, to reprobate burials in great towns or their vicinity.

Such bodies as are interred alone, in the midst of a great quantity of humid earth, are totally destroyed by passing through the successive degrees of the ordinary putrefaction; and this destruction is more speedy, the warmer the temperature. But if these insulated bodies be dry and emaciated; if the place of deposition be likewise dry, and the locality and other circumstances such, that the earth, so far from receiving moisture from the atmosphere, becomes still more effectually parched by the solar rays;—the animal juices are volatilized and absorbed, the solids contract and harden, and a peculiar species of mummy is produced. But every circumstance is very different in the common burying-grounds. Heaped together almost in contact, the influence of external bodies affects them scarcely at all, and they become abandoned to a peculiar disorganization, which destroys their texture, and produces the new and most permanent state of combination here described. From various observations which I do not here extract, it was found, that this fatty matter was capable of enduring in these burying-places for thirty or forty years, and is at length corroded and carried off by the aqueous putrid humidity which there abounds.

Among other interesting facts afforded by the chemical examination of this substance, are the following from experiments by M. Fourcroy.

1. This substance is fused at a less degree of heat than that of boiling water, and may be purified by pressure through a cloth, which disengages a portion of fibrous and bony matter. 2. The process of destructive distillation by a very graduated heat was begun, but not completed on account of its tediousness, and the little promise of advantage it afforded. The products which came over were water charged with volatile alkali, a fat oil, concrete volatile alkali, and no elastic fluid during the time the operation was continued. 3. Fragments of the fatty matter exposed to the air during the hot and dry summer of 1786 became dry, brittle, and almost pulverulent at the surface. On a careful examination, certain portions were observed to be semi-transparent, and more brittle than the rest. These possessed all the apparent properties of wax, and did not afford volatile alkali by distillation. 4. With water this fatty matter exhibited all the appearances of soap, and afforded a strong lather. The dried substance did not form the saponaceous combination with the same facility or perfection as that which was recent. About two-thirds of this dried matter separated from the water by cooling, and proved to be the semi-transparent substance resembling wax. This was taken from the surface of the soapy liquor, which being then passed through the filter, left a white soft shining matter, which was fusible and combustible. 5. Attempts were made to ascertain the quantity of volatile alkali in this substance by the application of lime, and of the fixed alkalis, but without success: for it was difficult to collect and appreciate the first portions which escaped, and likewise to disengage the last portions. The caustic volatile alkali, with the assistance of a gentle heat, dissolved the fatty matter, and the solution became perfectly clear and transparent at the boiling temperature of the mixture, which was 185° F. 6. Sulphuric acid, of the specific gravity of 2.0, was poured upon six times its weight of the fatty matter, and mixed by agitation. Heat was produced, and a gas or effluvium of the most insupportable putrescence was emitted, which infected the air of an extensive laboratory for several days. M. Fourcroy says, that the smell cannot be described, but that it is one of the most horrid and repulsive that can be imagined. It did not, however, produce any indisposition either in himself or his assistants. By dilution with water, and the ordinary processes of evaporation and cooling, properly repeated, the sulphates of ammonia, and of lime were obtained. A substance was separated from the liquor, which appeared to be the waxy matter, somewhat altered by the action of the acid. 7. The nitrous and muriatic acids were also applied, and afforded phenomena worthy of remark, but which for the sake of conciseness are here omitted. 8. Alcohol does not act on this matter at the ordinary temperature of the air But by boiling it dissolves one-third of its own weight, which is almost totally separable by cooling as low as 55°. The alcohol, after this process, affords by evaporation a portion of that waxy matter which is separable by acids, and is therefore the only portion soluble in cold alcohol. The quantity of fatty matter operated on, was 4 ounces, or 2304 grains, of which the boiling spirit took up the whole except 26 grains, which proved to be a mixture of 20 grains of ammoniacal soap, and 6 or 8 grains of the phosphates of soda and of lime. From this experiment, which was three times repeated with similar results, it appears that alcohol is well suited to afford an analysis of the fatty matter. It does not dissolve the neutral salts; when cold it dissolves that portion of concrete animal oil from which the volatile alkali had flown off, and when heated it dissolves the whole of the truly saponaceous matter, which is afterwards completely separated by cooling. And accordingly it was found, that a thin plate of the fatty matter, which had lost nearly the whole of its volatile alkali, by exposure to the air for three years, was almost totally dissolved by the cold alcohol.

The concrete oily or waxy substance obtained in these experiments constitutes the leading object of research, as being the peculiar substance with which the other well known matters are combined. It separates spontaneously by the action of the air, as well as by that of acids. These last separate it in a state of greater purity the less disposed the acid may be to operate in the way of combustion. It is requisite, therefore, for this purpose, that the fatty matter should be previously diffused in 12 times its weight of hot water; and the muriatic or acetous acid is preferable to the sulphuric or the nitrous. The colour of the waxy matter is grayish; and though exposure to the air, and also the action of the oxygenated muriatic acid did produce an apparent whiteness, it nevertheless disappeared by subsequent fusion. No method was discovered by which it could be permanently bleached.

The nature of this wax or fat is different from that of any other known substance of the like kind. When slowly cooled after fusion, its texture appears crystalline or shivery, like spermaceti; but a speedy cooling gives it a semi-transparency resembling wax. Upon the whole, nevertheless, it seems to approach more nearly to the former than to the latter of these bodies. It has less smell than spermaceti, and melts at 127° F.; Dr. Bostock says 92°. Spermaceti requires 6° more of heat to fuse it, (according to Dr. Bostock 20°). The spermaceti did not so speedily become brittle by cooling as the adipocere. One ounce of alcohol of the strength between 39 and 40 degrees of Baume's areometer, dissolved when boiling hot 12 gros of this substance, but the same quantity in like circumstances dissolved only 30 or 36 grains of spermaceti. The separation of these matters was also remarkably different, the spermaceti being more speedily deposited, and in a much more regular and crystalline form. Ammonia dissolves with singular facility, and even in the cold, this concrete oil separated from the fatty matter; and by heat it forms a transparent solution, which is a true soap. But no excess of ammonia can produce such an effect with spermaceti.

M. Fourcroy concludes his memoir with some speculations on the change to which animal substances in peculiar circumstances are subject. In the modern chemistry, soft animal matters are considered as a composition of the oxides of hydrogen and carbonated azote, more complicated than those of vegetable matters, and therefore more incessantly tending to alteration. If then the carbon be conceived to unite with the oxygen, either of the water which is present, or of the other animal matters, and thus escape in large quantities in the form of carbonic acid gas, we shall perceive the reason why this conversion is attended with so great a loss of weight, namely, about nine-tenths of the whole. The azote, a principle so abundant in animal matters, will form ammonia by combining with the hydrogen; part of this will escape in the vaporous form, and the rest will remain fixed in the fatty matter. The residue of the animal matters deprived of a great part of their carbon, of their oxygen, and the whole of their azote, will consist of a much greater proportion of hydrogen, together with carbon and a minute quantity of oxygen. This, according to the theory of M. Fourcroy, constitutes the waxy matter, or adipocere, which in combination with ammonia forms the animal soap, into which the dead bodies are thus converted.

Muscular fibre, macerated in dilute nitric acid, and afterwards well washed in warm water, affords pure adipocere, of a light yellow colour, nearly of the consistence of tallow, of a homogeneous texture, and of course free from ammonia. This is the mode in which it is now commonly procured for chemical experiment.

Ambergris appears to contain adipocere in large quantity, rather more than half of it being of this substance.

* This curious substance has been more recently examined by Chevreul. He found it composed of a small quantity of ammonia, potash, and lime, united to much margarine, and to a very little of another fatty matter different from that. Weak muriatic acid seizes the three alkaline bases. On treating the residue with a solution of potash, the margarine is precipitated in the form of a pearly substance, while the other fat remains dissolved. Fourcroy being of opinion that the fatty matter of animal carcases, the substance of biliary calculi, and spermaceti, were nearly identical, gave them the same name of adipocere; but it appears from the researches of M. Chevreul that these substances are very different from each other.

In the Philosophical Transactions for 1813 there is a very interesting paper on the above subject by Sir E. Home and Mr. Brande. He adduces many curious facts to prove that adipocere is formed by an incipient and incomplete putrefaction. Mary Howard, aged 44, died on the 12th May 1790, and was buried in a grave ten feet deep at the east end of Shoreditch church-yard, ten feet to the east of the great common sewer, which runs from north to south, and has always a current of water in it, the usual level of which is eight feet below the level of the ground, and two feet above the level of the coffins in the graves. In August 1811 the body was taken up, with some others buried near it, for the purpose of building a vault, and the flesh in all of them was converted into adipocere or spermaceti. At the full and new moon the tide raises water into the graves. which at other times are dry. To explain the extraordinary quantities of fat or adipocere formed by animals of a certain intestinal construction, Sir E. observes, that the current of water which passes through their colon, while the loculated lateral parts are full of solid matter, places the solid contents in somewhat similar circumstances to dead bodies in the banks of a common sewer.

The circmstance of ambergris, which contains 60 per cent. of fat, being found in immense quantities in the lower intestines of the spermaceti whales, and never higher up than seven feet from the anus, is an undeniable proof of fat being formed in the intestines; and as ambergris is only met with in whales out of health, it is most probably collected there, from the absorbents, under the influence of disease, not acting so as to take it into the constitution. In the human colon, solid masses of fat are sometimes met with in a diseased state of that canal, and are called *scybala*. A description and analysis by Dr. Ure of a mass of ambergris, extracted in Perthshire from the rectum of a living woman, were published in a London Medical Journal in September 1817. There is a case communicated by Dr. Babington, of fat formed in the intestines of a girl four and a half years old, and passing off by stool. Mr. Brande found, on the suggestion of Sir E. Home, that muscle digested in bile, is convertible into fat, at the temperature of about 100°. If the substance, however, pass rapidly into putrefaction, no fat is formed. Fæces voided by a gouty gentleman after six days constipation, yielded, on infusion in water, a fatty film. This process of forming fat in the lower intestines by means of bile throws considerable light upon the nourishment derived from clysters, a fact well ascertained, but which could not be explained. It also accounts for the wasting of the body which so invariably attends all complaints of the lower bowels. It accounts too for all the varieties in the turns of the colon, which we meet with in so great a degree in different animals. This property of the bile explains likewise the formation of fatty concretions in the gall bladder so commonly met with, and which, from these experiments, appear to be produced by the action of the bile on the mucus secreted in the gall bladder; and it enables us to understand how want of the gall bladder in children, from mal-formation, is attended with excessive leanness, notwithstanding a great appetite, and leads to an early death. Fat thus appears to be formed in the intestines, and from thence received into the circulation, and deposited in almost every part of the body. And as there appears to be no direct channels by which any superabundance of it can be thrown out of the body, whenever its supply exceeds the consumption, its accumulation becomes a disease, and often a very distressing one. See **Biliary** concretions and **Margarine**.*

* **Adit**, in mining, is a subterraneous passage slightly inclined, about six feet high and two or three feet wide, begun at the bottom of a neighbouring valley and continued up to the vein, for the purpose of carrying out the minerals and drawing off the water. If the mine require draining by a steam-engine from a greater depth, the water need be raised only to the level of the adit. There is a good account of the *Cornish adits* by Mr. W. Phillips, Trans. Geol. Soc. vol. ii.; and of adits in general, article *Galerie*, Brongniart's Mineralogy, vol. ii.*

Adopter. A vessel with two necks placed between a retort and a receiver, and serving to increase the length of the neck of the former. See **Laboratory.**

* **Adularia.** See **Feldspar.***

Aerated Alkaline Water. See **Acid** (**Carbonic**).

Aerial Acid. See **Acid** (**Carbonic**).

* **Aerolite or Meteoric Stone.** See **Meteorolite.***

* **Aerometer.** The name given by Dr. M. Hall to an ingenious instrument of his invention for making the necessary corrections in pneumatic experiments, to ascertain the mean bulk of the gases. It consists of a bulb of glass 4½ cubic inches capacity, blown at the end of a long tube whose capacity is one cubic inch. This tube is inserted into another tube of nearly equal length, supported on a sole. The first tube is sustained at any height within the second by means of a spring. Five cubic inches of atmospheric air, at a medium pressure and temperature, are to be introduced into the bulb and tube, of the latter of which it will occupy one-half; the other half of this tube, and part of the tube into which it is inserted, are to be occupied by the fluid of the pneumatic trough, whether water or mercury. The point of the tube at which the air and fluid meet, is to be marked by the figure 5, denoting 5 cubic inches. The upper and lower halves of the tube are each divided into 5 parts, representing tenths of a cubic inch. The external tube has a scale of inches attached. *Journal of Science, vol. v.* See **Gas.***

* **Aerostation.** A name commonly, but not very correctly, given to the art of raising heavy bodies into the atmosphere, by the buoyancy of heated air, or gases of small specific gravity, enclosed in a bag, which, from being usually of a spheroidal form, is called a balloon. Of all the possible shapes, the globular admits the greatest capacity under the least surface. Hence, of two bags of the same capacity, if one be spherical, and the other of any other shape, the former will contain the least quantity

of cloth, of the least surface. The spheroidal form is therefore best fitted for aërostation. Varnished lutestring or muslin is employed for the envelopes. The following table shows the relation betwixt the diameters, surfaces, and capacities of spheres:

Diameters.	Surfaces.	Capacities.
1	3.141	0.523
2	12.567	4.188
3	28.274	14.137
4	50.265	33.51
5	78.54	65.45
10	314.159	523.6
15	706.9	1767.1
20	1256.6	4189.
25	1963.5	8181.
30	2827.	14137.
40	5026.	33510.

Having ascertained by experiment the weight of a square foot of the varnished cloth, we find, by inspection in the above table, a multiplier whence we readily compute the total weight of the balloon. A cubic foot of atmospheric air weighs 527 gr. and a cubic foot of hydrogen about 40. But as the gas employed to fill balloons is never pure, we must estimate its weight at something more. And perhaps, taking every thing into account, we shall find it a convenient and sufficiently precise rule for aërostation, to consider every cubic foot of included gas, to have by itself a bouyancy of fully one ounce avoirdupois. Hence a balloon of 10 feet diameter will have an ascensional force of fully 524 oz. or 33 lbs. *minus* the weight of the 314 superficial feet of cloth; and one of 30 feet diameter, a buoyancy of fully 14137 oz. or nearly 890 lbs. *minus* the weight of the 2827 feet of cloth. On this calculation no allowance need be made for the seams of the balloon. See the article VARNISH.*

ÆTITES, or EAGLE STONE, is a name that has been given to a kind of hollow geodes of oxide of iron, often mixed with a larger or smaller quantity of silex and alumina, containing in their cavity some concretions, which rattle on shaking the stone. It is of a dull pale colour, composed of concentric layers of various magnitudes, of an oval or polygonal form, and often polished. Eagles were said to carry them to their nests, whence their name; and superstition formerly ascribed wonderful virtues to them.

AFFINITY (CHEMICAL). See ATTRACTION (CHEMICAL).

AGALMATOLITE. See BILDSTEIN.

AGARICUS. The mushroom, a genus of the order Fungi. Mushrooms appear to approach nearer to the nature of animal matter, than any other productions of the vegetable kingdom, as beside hydrogen, oxygen, and carbon, they contain a considerable portion of nitrogen, and yield ammonia by distillation. Prof. Proust has likewise discovered in them the benzoic acid, and phosphate of lime.

A few of the species are eaten in this country, but many are recorded to have produced poisonous effects; though in some foreign countries, particularly in Russia, very few are rejected. Perhaps it is of importance, that they should be fresh, thoroughly dressed, and not of a coriaceous texture. The Russians, however, are very fond of the *A. piperatus*, which we deem poisonous, preserved with salt throughout the winter: and our *ketchup* is made by sprinkling mushrooms with salt, and letting them stand till great part is resolved into a brown liquor, which is then boiled up with spices. The *A. piperatus* has been recommended in France to consumptive people. The *A. muscarius* has been prescribed in doses of a few grains in cases of epilepsy and palsy, subsequent to the drying up of eruptions.

In pharmacy two species of *boletus* have formerly been used under the name of agaric. The *B. pini laricis*, or *male agaric* of the shops, was given as a purgative, either in substance, or in an extract made with vinegar, wine, or an alkaline solution: and the *B. igniarius*, spunk, or touchwood, called female agaric, was applied externally as a styptic, even after amputations. For this purpose the soft inner substance was taken, and beaten with a hammer to render it still softer. That of the oak was preferred.

* The mushrooms, remarkable for the quickness of their growth, and decay, as well as for the fœtor attending their spontaneous decomposition, were unaccountably neglected by analytical chemists, though capable of rewarding their trouble, as is evinced by the recent investigations and discoveries of MM. Vauquelin and Braconnot. The insoluble fungous portion of the mushroom, though it resembles woody fibre in some respects, yet being less soluble than it in alkalis, and yielding a nutritive food, is evindently a peculiar product, to which accordingly the name of fungin has been given. Two new vegetable acids, the boletic and fungic, were also fruits of these researches.

1. *Agaricus campestris*, an ordinary article of food, analyzed by Vauquelin, gave the following constituents: 1. Adipocere. On expressing the juice of the agaric, and subjecting the remainder to the action of of boiling alcohol, a fatty matter is extracted, which falls down in white flakes as the alcohol cools. It has a dirty white colour, a fatty feel like spermaceti, and, exposed to heat, soon melts, and then exhales the odour of grease; 2. An oily matter; 3. Vegetable albumen; 4. The sugar of mushrooms; 5. An animal matter soluble in water and alcohol: On being

heated it evolves the odour of roasting meat, like osmazome; 6. An animal matter not soluble in alcohol; 7. Fungin; 8. Acetate of potash.

2. *Agaricus volvaceus* afforded Braconnot fungin, gelatin, vegetable albumen much phosphate of potash, some acetate of potash, sugar of mushrooms, a brown oil, adipocere, wax, a very fugaceous deleterious matter, uncombined acid, supposed to be the acetic, benzoic acid, muriate of potash, and a deal of water; in all 14 ingredients.

3. *Agaricus acris* or *piperatus*, was found by Braconnot, after a minute analysis, to contain nearly the same ingredients as the preceding, without the wax and benzoic acid, but with more adipocere.

4. *Agaricus stypticus*. From twenty parts of this, Braconnot obtained of resin and adipocere 1.8, fungin 16.7, of an unknown gelatinous substance, a potash salt, and a fugaceous acrid principle 1.5.

5. *Agaricus bulbosus*, was examined by Vauquelin, who found the following constituents; an animal matter insoluble in alcohol, osmazome, a soft fatty matter of a yellow colour and acrid taste, an acid salt, (not a phosphate). The insoluble substances of the agaric yielded an acid by distillation. In Orfila's Toxicology several instances are detailed of the fatal effects of this species of mushroom on the human body. Dogs were killed within 24 hours by small quantities of it in substance, and also by its watery and alcoholic infusions, but water distilled from it was not injurious. It is curious that the animals experienced little inconvenience after swallowing it, during the first ten hours; stupor, cholera, convulsions, and painful cramps are the usual symptoms of the poison in men. The best remedy is an emetic.

6. *Agaricus theogolus*. In this Vauquelin found sugar of mushrooms, osmazome, a bitter acrid fatty matter, an animal matter not soluble in alcohol, a salt containing a vegetable acid.

7. *Agaricus muscarius*, Vauquelin's analysis of this species is as follows: The two animal matters of the last agaric, a fatty matter, sulphate, phosphate, and muriate of potash, a volatile acid from the insoluble matter. The following account from Orfila of the effects of this species on the animal economy is interesting. Several French soldiers ate, at two leagues from Poloeck in Russia, mushrooms of the above kind. Four of them, of a robust constitution, who conceived themselves proof against the consequences, under which their feebler companions were beginning to suffer, refused obstinately to take an emetic. In the evening the following symptoms appeared: Anxiety, sense of suffocation, ardent thirst, intense griping pains, a small and irregular pulse, universal cold sweats, changed expression of countenance, violet tint of the nose and lips, general trembling, fetid stools. These symptoms becoming worse, they were carried to the hospital. Coldness and livid colour of the limbs, a dreadful delirium, and acute pains, accompanied them to the last moment. One of them sunk a few hours after his admission into the hospital; the three others had the same fate in the course of the night. On opening their dead bodies, the stomach and intestines displayed large spots of inflammation and gangrene; and putrefaction seemed advancing very rapidly.*

Agaricus mineralis, the *mountain milk*, or *mountain meal*, of the Germans, is one of the purest of the native carbonates of lime, found chiefly in the clefts of rocks and at the bottom of some lakes, in a loose or semi-indurated form. It has been used internally in hæmorrhages, strangury, gravel, and dysenteries; and externally as an application to old ulcers, and weak and watery eyes.

M. Fabroni calls by the name of *mineral agaric*, or *fossil meal*, a stone of a loose consistence found in Tuscany in considerable abundance, of which bricks may be made, either with or without the addition of a twentieth part of argil, so light as to float in water; and which he supposes the ancients used for making their floating bricks. This, however, is very different from the preceding, not being even of the calcareous genus, since it appears, on analysis, to consist of silex 55 parts, magnesia 15, water 14, argil 12, lime 3, iron 1. Kirwan calls it *argillo-murite*.

* Agate A mineral, whose basis is calcedony, blended with variable proportions of jasper, amethyst, quartz, opal, heliotrope, and carnelian. *Ribbon agate* consists of alternate and parallel layers of calcedony with jasper, or quartz, or amethyst. The most beautiful comes from Siberia and Saxony. It occurs in porphyry and gneiss.—*Brecciated agate;* a base of amethyst, containing fragments of ribbon agate, constitute this beautiful variety. It is of Saxon origin.—*Fortification agate*, is found in nodules of various imitative shapes, imbedded in amygdaloid. This happens at Oberstein on the Rhine, and in Scotland. On cutting it across and polishing it, the interior zig-zag parallel lines bear a considerable resemblance to the plan of a modern fortification. In the very centre, quartz and amethyst are seen in a splintery mass, surrounded by the jasper and calcedony.—*Mocha stone*. Translucent calcedony, containing dark outlines of arborization, like vegetable filaments, is called Mocha stone, from the place in Arabia

where it is chiefly found. These curious appearances were ascribed to deposites of iron or manganese, but more lately they have been thought to arise from mineralized plants of the cryptogamous class.—*Moss agate*, is a calcedony with variously coloured ramifications of a vegetable form, occasionally traversed with irregular veins of red jasper. Dr. M'Culloch has recently detected, what Daubenton merely conjectured, in mocha and moss agates, aquatic confervæ, unaltered both in colour and form, and also coated with iron oxide. Mosses and lichens have also been observed, along with chlorite, in vegetations. An onyx agate set in a ring, belonging to the Earl of Powis, contains the chrysalis of a moth. Agate is found in most countries, chiefly in trap rocks, and serpentine. Hollow nodules of agate called *geodes*, present interiorly crystals of quartz, colourless or amethystine, having occasionally scattered crystals of stilbite, chabasie, and capillary mesotype. These geodes are very common. Bitumen has been found by M. Patrin in the inside of some of them, among the hills of Dauria, on the right bank of the Chilca. The small geodes of volcanic districts contain water occasionally in their cavities. These are chiefly found in insulated blocks of a lava having an earthy fracture. When they are cracked, the liquid escapes by evaporation; it is easily restored by plunging them for a little in hot water. Agates are artificially coloured by immersion in metallic solutions. Agates were more in demand formerly than at present. They were cut into cups and plates for boxes; and also into cutlass and sabre handles. They are still cut and polished on a considerable scale and at a moderate price, at Oberstein. The surface to be polished is first coarsely ground by large millstones of a hard reddish sandstone, moved by water. The polish is afterwards given on a wheel of soft wood, moistened and imbued with a fine powder of a hard red *tripoli* found in the neighbourhood. M. Faujas thinks that this *tripoli* is produced by the decomposition of the porphyrated rock that serves as a gangue to the agates. The ancients employed agates for making cameos. (See CALCEDONY.) Agate mortars are valued by analytical chemists, for reducing hard minerals to an impalpable powder. For some interesting optical properties of agates, see LIGHT.*

The oriental agate is almost transparent, and of a vitreous appearance. The occidental is of various colours, and often veined with quartz or jasper. It is mostly found in small pieces covered with a crust, and often running in veins through rocks like flint and petrosilex, from which it does not seem to differ greatly. Agates are most prized, when the internal figure nearly resembles some animal or plant.

AGGREGATE. When bodies of the same kind are united, the only consequence is, that one larger body is produced. In this case, the united mass is called an aggregate, and does not differ in its chemical properties from the bodies from which it was originally made. Elementary writers call the smallest parts into which an aggregate can be divided without destroying its chemical properties, integrant parts. Thus the integrant parts of common salt are the smallest parts which can be conceived to remain without change; and beyond these, any further subdivision cannot be made without developing the component parts, namely, the alkali and the acid; which are still further resolvable into their constituent principles.

* AGRICULTURE, considered as a department of chemistry, is a subject of vast importance, but hitherto much neglected. When we consider that every change in the arrangements of matter is connected with the growth and nourishment of plants; the comparative values of their produce as food; the composition and constitution of soils; and the manner in which lands are enriched by manure, or rendered fertile by the different processes of cultivation, we shall not hesitate to assign to chemical agriculture, a high place among the studies of man. If land be unproductive, and a system of ameliorating it is to be attempted, the sure method of attaining this object is by determining the causes of its sterility, which must necessarily depend upon some defect in the constitution of the soil, which may easily be discovered by chemical analysis. Some lands of good apparent texture are yet eminently barren; and common observation and common practice afford no means of ascertaining the cause, or of removing the effect. The application of chemical tests in such cases is obvious; for the soil must contain some noxious principle which may be easily discovered, and probably easily destroyed. Are any of the salts of iron present? They may be decomposed by lime. Is there an excess of siliceous sand? The system of improvement must depend on the application of clay and calcareous matter. Is there a defect of calcareous matter? The remedy is obvious. Is an excess of vegetable matter indicated? It may be removed by liming, paring, and burning. Is there a deficiency of vegetable matter? It is to be supplied by manure. Peat earth is a manure; but there are some varieties of peats which contain so large a quantity of ferruginous matter as to be absolutely poisonous to plants. There has been no question on which more difference of opinion has existed, than that of the state in

which manure ought to be ploughed into land; whether recent, or when it has gone through the process of fermentation. But whoever will refer to the simplest principles of chemistry, cannot entertain a doubt on the subject. As soon as dung begins to decompose, it throws off its volatile parts, which are the most valuable and most efficient. Dung which has fermented so as to become a mere soft cohesive mass, has generally lost from one-third to one-half of its most useful constituent elements. See the articles, ANALYSIS, MANURE, SOILS, VEGETATION, and Sir H. Davy's Agricult. Chem.*

AIR was, till lately, used as the generic name for such invisible and exceedingly rare fluids as possess a very high degree of elasticity, and are not condensable into the liquid state by any degree of cold hitherto produced; but as this term is commonly employed to signify that compound of aëriform fluids which constitutes our atmosphere, it has been deemed advisable to restrict it to this signification, and to employ as the generic term the word GAS, (which see,) for the different kinds of air, except what relates to our atmospheric compound.

AIR (ATMOSPHERICAL or COMMON). The immense mass of permanently elastic fluid which surrounds the globe we inhabit, must consist of a general assemblage of every kind of air which can be formed by the various bodies that compose its surface. Most of these, however, are absorbed by water; a number of them are decomposed by combination with each other; and some of them are seldom disengaged in considerable quantities by the processes of nature. Hence it is that the lower atmosphere consists chiefly of oxygen and nitrogen, together with moisture and the occasional vapours or exhalations of bodies. The upper atmosphere seems to be composed of a large proportion of hydrogen, a fluid of so much less specific gravity than any other, that it must naturally ascend to the highest place, where, being occasionally set on fire by electricity, it appears to be the cause of the aurora borealis and fire-balls. It may easily be understood, that this will only happen on the confines of the respective masses of common atmospherical air, and of the inflammable air; that the combustion will extend progressively, though rapidly, in flashings from the place where it commences; and that when by any means a stream of inflammable air, in its progress toward the upper atmosphere, is set on fire at one end, its ignition may be much more rapid than what happens higher up, where oxygen is wanting, and at the same time more definite in its figure and progression, so as to form the appearance of a fire-ball.

* To the above speculations, it may probably be objected, that the air on the summit of Mont Blanc, and that brought down from still greater heights by M. Gay-Lussac, in an aërostatic machine, gave, on analysis, no product of hydrogen. But the lowest estimate of the height of luminous meteors, is prodigiously greater than the highest elevations to which man has reached.* See COMBUSTION.

That the air of the atmosphere is so transparent as to be invisible, except by the blue colour it reflects when in very large masses, as is seen in the sky or region above us, or in viewing extensive landscapes; that it is without smell, except that of electricity, which it sometimes very manifestly exhibits; altogether without taste, and impalpable: not condensable by any degree of cold into the dense fluid state, though easily changing its dimensions with its temperature; that it gravitates and is highly elastic, are among the numerous observations and discoveries, which do honour to the sagacity of the philosophers of the seventeenth century. They likewise knew that this fluid is indispensably necessary to combustion; but no one, except the great, though neglected, John Mayow, appears to have formed any proper notion of its manner of acting in that process.

The air of the atmosphere, like other fluids, appears to be capable of holding bodies in solution. It takes up water in considerable quantities, with a diminution of its own specific gravity; from which circumstance, as well as from the consideration that water rises very plentifully in the vaporous state *in vacuo*, it seems probable, that the air suspends vapour, not so much by a real solution, as by keeping its particles asunder, and preventing their condensation. Water likewise dissolves or absorbs air.

Mere heating or cooling does not affect the chemical properties of atmospherical air; but actual combustion, or any process of the same nature, combines its oxygen, and leaves its nitrogen separate. Whenever a process of this kind is carried on in a vessel containing atmospherical air, which is enclosed either by inverting the vessel over mercury, or by stopping its aperture in a proper manner, it is found that the process ceases after a certain time; and that the remaining air, *(if a combustible body capable of solidifying the oxygen, such as phosphorus, have been employed,)* has lost about a fifth part of its volume, and is of such a nature as to be incapable of maintaining any combustion for a second time, or of supporting the life of animals. From these experiments it is clear, that one of the following deductions must be true:—1. The combustible body has emitted some principle, which, by combining with the air, has rendered it unfit for the purpose of further combustion; or, 2. It has absorbed part of the air which was fit for that purpose, and has left a residue of a different nature; or, 3. Both events have happened; namely, that the pure part of the air has been absorbed, and a principle has been emitted, which has changed the original properties of the remainder.

The facts must clear up these theories. The first induction cannot be true, because the residual air is not only of less bulk, but of less specific gravity, than before. The air cannot therefore have received so much as it has lost. The second is the doctrine of the philosophers who deny the existence of phlogiston, or a principle of inflammability; and the third must be adopted by those who maintain that such a principle escapes from bodies during combustion. This residue was called phlogisticated air, in consequence of such an opinion.

In the opinion that inflammable air is the phlogiston, it is not necessary to reject the second inference, that the air has been no otherwise changed than by the mere subtraction of one of its principles: for the pure or vital part of the air may unite with inflammable air supposed to exist in a fixed state in the combustible body; and if the product of this union still continues fixed, it is evident, that the residue of the air after combustion will be the same as it would have been, if the vital part had been absorbed by any other fixed body. Or, if the vital air be absorbed, while inflammable air or phlogiston is disengaged, and unites with the aëriform residue, this residue will not be heavier than before, unless the inflammable air it has gained exceeds in weight the vital air it has lost; and if the inflammable air falls short of that weight, the residue will be lighter.

These theories it was necessary to mention; but it has been sufficiently proved by various experiments, that combustible bodies take oxygen from the atmosphere, and leave nitrogen; and that when these two fluids are again mixed, in due proportions, they compose a mixture not differing from atmospherical air.

The respiration of animals produces the same effect on atmospherical air as combustion does, and their constant heat appears to be an effect of the same nature. When an animal is included in a limited quantity of atmospherical air, it dies as soon as the oxygen is consumed; and no other air will maintain animal life but oxygen, or a mixture which contains it. Pure oxygen maintains the life of animals much longer than atmospherical air, bulk for bulk.

* It is to be particularly observed, however, that, in many cases of combustion, the oxygen of the air, in combining with the combustible body, produces a compound, not solid or liquid, but aëriform. The residual air will therefore be a mixture of the nitrogen of the atmosphere with the consumed oxygen, converted into another gas. Thus, in burning charcoal, the carbonic acid gas generated, mixes with the residual nitrogen, and makes up exactly, when the effect of heat ceases, the bulk of the original air. The breathing of animals, in like manner, changes the oxygen into carbonic acid gas, without altering the atmospherical volume.*

There are many provisions in nature by which the proportion of oxygen in the atmosphere, which is continually consumed in respiration and combustion, is again restored to that fluid. In fact there appears, as far as an estimate can be formed of the great and general operations of nature, to be at least as great an emission of oxygen, as is sufficient to keep the general mass of the atmosphere at the same degree of purity. Thus, in volcanic eruptions there seems to be at least as much oxygen emitted or extricated by fire from various minerals, as is sufficient to maintain the combustion, and perhaps even to meliorate the atmosphere. And in the bodies of plants and animals, which appear in a great measure to derive their sustenance and augmentation from the atmosphere and its contents, it is found that a large proportion of nitrogen exists. Most plants emit oxygen in the sunshine, from which it is highly probable that they imbibe and decompose the air of the atmosphere, retaining carbon, and emitting the vital part. Lastly, if to this we add the decomposition of water, there will be numerous occasions in which this fluid will supply us with disengaged oxygen; while, by a very rational supposition, its hydrogen may be considered as having entered into the bodies of plants for the formation of oils, sugars, mucilages, &c. from which it may be again extricated.

To determine the respirability or purity of air, it is evident that recourse must be had to its comparative efficacy in maintaining combustion, or some other equivalent process. This subject will be considered under the article EUDIOMETER.

From the latest and most accurate experiments, the proportion of oxygen in atmospheric air is by measure about 21 per cent; and it appears to be very nearly the same, whether it be in this country or on the coast of Guinea, on low plains or lofty mountains, or even at the height of 7250 yards above the level of the sea, as ascertained by Gay-Lussac in his aërial voyage in September 1805. The remainder of the air is nitrogen, with a small portion of aqueous vapour, amounting to about 1 per cent. in the driest weather, and a still less portion of carbonic acid, not exceeding a thousandth part of the whole.

As oxygen and nitrogen differ in specific gravity in the proportion of 135 to 121, according to Kirwan, and of 139 to 120 according to Davy, it has been presumed, that the oxygen would be more abundant in the lower regions, and the nitrogen in the higher, if they constituted a mere mechanical mixture, which appears contrary to the fact. On the other hand it has been urged, that they cannot be in the state of chemical combination, because they both retain their distinct properties unaltered, and no change of temperature or density takes place on their union. But perhaps it may be said, that, as they have no repugnance to mix with each other, as oil and water have, the continual agitation to which the atmosphere is exposed, may be sufficient to prevent two fluids, differing not more than oxygen and nitrogen in gravity, from separating by subsidence, though simply mixed. On the contrary, it may be argued, that to say chemical combination cannot take place without producing new properties, which did not exist before in the component parts, is merely begging the question; for though this generally appears to be the case, and often in a very striking manner, yet combination does not always produce a change of properties, as appears in M. Biot's experiments with various substances, of which we may instance water, the refraction of which is precisely the mean of that of the oxygen and hydrogen, which are indisputably combined in it.

To get rid of the difficulty, Mr. Dalton of Manchester framed an ingenious hypothesis, that the particles of different gases neither attract nor repel each other; so that one gas expands by the repulsion of its own particles, without any more interruption from the presence of another gas, than if it were in a vacuum. This would account for the state of atmospheric air, it is true; but it does not agree with certain facts. In the case of the carbonic acid gas in the Grotto del Cano, and over the surface of brewers' vats, why does not this gas expand itself freely upward, if the superincumbent gases do not press upon it? Mr. Dalton himself too instances as an argument for his hypothesis, that oxygen and hydrogen gases, when mixed by agitation, do not separate on standing. But why should either oxygen or hydrogen require agitation, to diffuse it through a vacuum, in which, according to Mr. Dalton, it is placed?—*C.*

The theory of Berthollet appears consistent with all the facts, and sufficient to account for the phenomenon. If two bodies be capable of chemical combination, their particles must have a mutual attraction for each other. This attraction, however, may be so opposed by concomitant circumstances, that it may be diminished in any degree. Thus we know, that the affinity of aggregation may occasion a body to combine slowly with a substance for which it has a powerful affinity, or even entirely prevent its combining with it; the presence of a third substance may equally prevent the combination; and so may the absence of a certain quantity of caloric. But in all these cases the attraction of the particles must subsist, though diminished or counteracted by opposing circumstances. Now we know that oxygen and nitrogen are capable of combination; their particles, therefore, must attract each other; but in the circumstances in which they are placed in our atmosphere, that attraction is prevented from exerting itself to such a degree as to form them into a chemical compound, though it operates with sufficient force to prevent their separating by their difference of specific gravity. Thus the state of the atmosphere is accounted for, and every difficulty obviated, without any new hypothesis.

* The exact specific gravity of atmospherical air, compared to that of water, is a very nice and important problem. By reducing to 60° Fahr. and to 30 inches of the barometer, the results obtained with great care by MM. Biot and Arago, the specific gravity of atmospherical air appears to be 0.001220, water being represented by 1.000000. This relation expressed fractionally is $\frac{1}{820}$ or water is 820 times denser than atmospherical air. Mr. Rice, in the 77th and 78th numbers of the Annals of Philosophy, deduces from Sir George Shuckburgh's experiments 0.00120855 for the specific gravity of air. This number gives water to air as 827.437 to 1. If with Mr. Rice we take the cubic inch of water = 252.525 gr. then 100 cubic inches of air by Biot's experiments will weigh 30.808 gr. and by Mr. Rice's estimate 30.519. He considers with Dr. Prout the atmosphere to be a compound of 4 volumes of nitrogen, and 1 of oxygen; the specific gravity of the first being to that of the second as 1.1111 to 0.9722.

Hence

0.8 vol. nitr.	sp. gr. 0.001166	=	0.000940
0.2 oxy.	0.001340	=	0.000268
			0.001208

The numbers are transposed in the Annals of Philosophy by some mistake.

MM. Biot and Arago found the specific gravity of oxygen to be - - 1.10359
and that of nitrogen, - - - - 0.96913
air being reckoned, - - - - 1.00000
Or compared to water as unity,—
Nitrogen is 0.001182338
Oxygen, 0.001346379
And 0.8 nitrogen = 0.00094587
0.2 oxygen = 0.00026927
0.00121514
And 0.79 nitrogen = 0.000934
0.21 oxygen = 0.000283
0.001217

A number which approaches very nearly to the result of experiment. Many analogies, it must be confessed, favour Dr. Prout's proportions; but the greater number of experiments on the composition and density of the atmosphere agree with Biot's results. Nothing can decide these fundamental chemical proportions except a new, elaborate, and most minutely accurate series of experiments. We shall then know whether the atmosphere contains in volume 20 or 21 per cent of oxygen. See **Meteorology**.*

Alabaster. Among the stones which are known by the name of marble, and have been distinguished by a considerable variety of denominations by statuaries, and others whose attention is more directed to their external character and appearance than their component parts, alabasters are those which have a greater or less degree of imperfect transparency, a granular texture, are softer, take a duller polish than marble, and are usually of a whiter colour. Some stones, however, of a veined and coloured appearance, have been considered as alabasters, from their possessing the first mentioned criterion; and some transparent and yellow sparry stones have also received this appellation.

Chemists are at present agreed in applying this name only to such opaque, consistent, and semi-transparent stones, as are composed of lime united with the sulphuric acid. But the term is much more frequent among masons and statuaries than chemists. Chemists in general confound the alabasters among the selenites, gypsums, or plaster of Paris, more especially when they allude only to the component parts, without having occasion to consider the external appearance, in which only these several compounds differ from each other.

As the semi-opaque appearance and granular texture arise merely from a disturbed or successive crystallization, which would else have formed transparent spars, it is accordingly found, that the calcareous stalactites, or drop-stones, formed by the transition of water through the roofs of caverns in a calcareous soil, do not differ in appearance from the alabaster, most of which is also formed in this manner. But the calcareous stalactites here spoken of consist of calcareous earth and carbonic acid; while the alabaster of the chemists is formed of the same earth and sulphuric acid, as has already been remarked.

* **Albin.** A mineral discovered at Monaberg, near Aussig, in Bohemia; and being of an opaque white colour, has been called, by Werner, *albin*. Aggregated crystalline laminæ constitute massive albin. Small crystals of it in right prisms, whose summits consist of four quadrangular planes, are found sprinkled over mammelated masses in cavities.* See **Zeolite**.

Album Græcum. Innumerable are the instances of fanciful speculation and absurd credulity in the invention and application of subjects in the more ancient materia medica. The white and solid excrement of dogs, which subsist chiefly on bones, has been received as a remedy in the medical art, under the name of Album Græcum. It consists, for the most part, of the earth of bones, or lime in combination with phosphoric acid.

Albumen. This substance, which derives its name from the Latin for the white of an egg, in which it exists abundantly, and in its purest natural state, is one of the chief constituent principles of all the animal solids. Beside the white of egg, it abounds in the serum of blood, the vitreous and crystalline humours of the eye, and the fluid of dropsy. Fourcroy claims to himself the honour of having discovered it in the green feculæ of plants in general, particularly in those of the cruciform order, in very young ones, and in the fresh shoots of trees, though Rouelle appears to have detected it there long before. Vauquelin says it exists also in the mineral water of Plombieres.

Mr. Seguin has found it in remarkable quantity in such vegetables as ferment without yeast, and afford a vinous liquor; and from a series of experiments he infers that albumen is the true principle of fermentation, and that its action is more powerful in proportion to its solubility, three different degrees of which he found it to possess.

The chief characteristic of albumen is its coagulability by the action of heat. If the white of an egg be exposed to a heat of about 134° F. white fibres begin to appear in it, and at 160° it coagulates into a solid mass. In a heat not exceeding 212° it dries, shrinks, and assumes the appearance of horn. It is soluble in cold water before it has been coagulated, but not after; and when diluted with a very large portion, it does not coagulate easily.

Pure alkalis dissolve it, even after coagulation. It is precipitated by muriate of mercury, nitro-muriate of tin, acetate of lead, nitrate of silver, muriate of gold, infusion of galls, and tannin. The acids and metallic oxides coagulate albumen. On the addition of concentrated sulphuric acid, it becomes black, and exhales a nauseous smell. Strong muriatic acid gives a violet tinge to the coagulum, and at length becomes saturated with ammonia. Nitric acid, at 70° F. disengages from it abundance of azotic gas; and if the heat be increased prussic acid is formed, after which carbonic acid and carburetted hydrogen are evolved, and the residue consists of water containing a little oxalic acid, and covered with a lemon coloured fat oil. If dry potash or soda be triturated with albumen, either liquid or solid, ammoniacal gas is evolved, and the calcination of the residuum yields an alkaline prussiate.

On exposure to the atmosphere in a moist state, albumen passes at once to the state of putrefaction.

* Solid albumen may be obtained by agitating white of egg with ten or twelve times its weight of alcohol. This seizes the water which held the albumen in solution; and this substance is precipitated under the form of white flocks or filaments, which cohesive attraction renders insoluble, and which consequently may be freely washed with water. Albumen thus obtained is like fibrin, solid, white, insipid, inodorous, denser than water, and without action on vegetable colours. It dissolves in potash and soda more easily than fibrin; but in acetic acid and ammonia with more difficulty. When these two animal principles are separately dissolved in potash, muriatic acid added to the albuminous does not disturb the solution, but it produces a cloud in the other.

Fourcroy and several other chemists have ascribed the characteristic coagulation of albumen by heat to its oxygenation. But cohesive attraction is the real cause of the phenomenon. In proportion as the temperature rises, the particles of water and albumen recede from each other, their affinity diminishes, and then the albumen precipitates. However, by uniting albumen with a large quantity of water, we diminish its coagulating property to such a degree, that heat renders the solution merely opalescent. A new-laid egg yields a soft coagulum by boiling; but when, by keeping, a portion of the water has transuded so as to leave a void space within the shell, the concentrated albumen affords a firm coagulum. An *analogous phenomenon* is exhibited by acetate of alumina, a solution of which, being heated, gives a precipitate in flakes, which redissolve as the caloric which separated the particles of acid and base escapes, or as the temperature falls. A solution containing $\frac{1}{10}$ of dry albumen forms by heat a solid *coagulum;* but when it contains only $\frac{1}{15}$, it gives a glairy liquid. One thousandth part, however, on applying heat, occasions opalescence. Putrid white of egg, and the *pus* of ulcers, have a similar smell. According to Dr. Bostock, a drop of a saturated solution of corrosive sublimate let fall into water containing $\frac{1}{2000}$ of albumen, occasions a milkiness and curdy precipitate. On adding a slight excess of the mercurial solution to the albuminous liquid, and applying heat, the precipitate which falls, being dried, contains in every 7 parts, 5 of albumen. Hence that salt is the most delicate test of this animal product. The yellow pitchy precipitate occasioned by tannin, is brittle when dried, and not liable to putrefaction. But tannin, or infusion of galls, is a much nicer test of gelatin than of albumen.

The cohesive attraction of coagulated albumen makes it resist putrefaction. In this state it may be kept for weeks under water without suffering change. By long digestion in weak nitric acid, albumen seems convertible into gelatin. By the analysis of Gay-Lussac and Thenard, 100 parts of albumen are formed of 52.883 carbon, 23.872 oxygen, 7.540 hydrogen, 15.705 nitrogen; or, in other terms, of 52.883 carbon, 27.127 oxygen and hydrogen, in the proportions for constituting water, 15.705 nitrogen, and 4.285 hydrogen in excess. The negative pole of a voltaic pile in high activity coagulates albumen; but if the pile be feeble, coagulation goes on only at the positive surface. Albumen, in such a state of concentration as it exists in serum of blood, can dissolve some metallic oxides, particularly the protoxide of iron. Orfila has found white of egg to be the best antidote to the poisoning effects of corrosive sublimate on the human stomach. As albumen occasions precipitates with the solutions of almost every metallic salt, probably it may act beneficially against other species of mineral poison.*

From its coagulability albumen is of great use in clarifying liquids. See CLARIFICATION.

It is likewise remarkable for the property of rendering leather supple, for which purpose a solution of whites of eggs in water is used by leather-dressers; and hence Dr. Lobb of Yeovil in Somersetshire was induced to employ this solution in cases of contraction and rigidity of the tendons, and derived from it apparent success.

Whites of eggs beaten in a basin with a lump of alum, till they coagulate, form the *alum curd* of Riverius, or *alum cataplasm* of the London Pharmacopœia, used to remove inflammations of the eyes.

* **Alburnum.** The interior white bark of trees.*

* **Alcarrazas.** A species of porous pottery made in Spain, for the purpose of cooling water by its transudation and copious evaporation from the sides of the vessel. M. Darcet gives the following as the analysis of the clay which is employed for the purpose: 60 calcareous earth, mixed with alumina and a little peroxide of iron, and 36 of siliceous earth, mixed with a little alumina. In working up the earths with water, a quantity of salt is added, and dried in it. The pieces are only half baked.*

* **Alchemy.** A title of dignity, given in the dark ages, by the adepts, to the mystical art by which they professed to find the philosopher's stone, that was to transmute base metals into gold, and prepare the elixir of life. Though avarice, fraud, and folly were their motives, yet their experimental researches were instrumental in promoting the progress of chemical discovery. Hence, in particular, metallic pharmacy derived its origin.*

Alcohol. This term is applied in strictness only to the pure spirit obtainable by distillation and subsequent rectification from all liquids that have undergone vinous fermentation, and from none but such as are susceptible of it. But it is commonly used to signify this spirit more or less imperfectly freed from water, in the state in which it is usually met with in the shops, and in which, as it was first obtained from the juice of the grape, it was long distinguished by the name of spirit of wine. At present it is extracted chiefly from grain or molasses in Europe, and from the juice of the sugar-cane in the West Indies; and in the diluted state in which it commonly occurs in trade, constitutes the basis of the several spirituous liquors called brandy, rum, gin, whiskey, and cordials, however variously denominated or disguised.

As we are not able to compound alcohol immediately from its ultimate constituents, we have recourse to the process of fermentation, by which its principles are first extricated from the substances in which they were combined, and then united into a new compound; to distillation, by which this new compound, the alcohol is separated in a state of dilution with water, and contaminated with essential oil; and to rectification, by which it is ultimately freed from these.

It appears to be essential to the fermentation of alcohol, that the fermenting fluid should contain saccharine matter, which is indispensable to that species of fermentation called vinous. In France, where a great deal of wine is made, particularly at the commencement of the vintage, that is too weak to be a saleable commodity, it is a common practice to subject this wine to distillation, in order to draw off the spirit; and as the essential oil that rises in this process is of a more pleasant flavour than that of malt or molasses, the French brandies are preferred to any other; though even in the flavour of these there is a difference, according to the wine from which they are produced. In the West Indies a spirit is obtained from the juice of the sugar-cane, which is highly impregnated with its essential oil, and well known by the name of *rum*. The distillers in this country use grain, or molasses, whence they distinguish the products by the name of *malt spirits*, and *molasses spirits*. It is said that a very good spirit may be extracted from the husks of gooseberries or currants, after wine has been made from them.

As the process of malting developes the saccharine principle of grain, it would appear to render it fitter for the purpose; though it is the common practice to use about three parts of raw grain with one of malt. For this, two reasons may be assigned: by using raw grain the expense of malting is saved, as well as the duty on malt; and the process of malting requires some nicety of attention, since, if it be carried too far, part of the saccharine matter is lost, and if it be stopped too soon, this matter will not be wholly developed. Besides, if the malt be dried too quickly, or by an unequal heat, the spirit it yields will be less in quantity, and more unpleasant in flavour. Another object of economical consideration is, what grain will afford the most spirit in proportion to its price, as well as the best in quality. Barley appears to produce less spirit than wheat; and if three parts of raw wheat be mixed with one of malted barley, the produce is said to be particularly fine. This is the practice of the distillers in Holland for producing a spirit of the finest quality; but in England they are expressly prohibited from using more than one part of wheat to two of other grain. Rye, however, affords still more spirit than wheat.

* The practice with the distillers in Scotland is to use one part of malted with from four to nine parts of unmalted grain. This mixture yields an equal quantity of spirit, and at a much cheaper rate than when the former proportions are taken.*

Whatever be the grain employed, it may be coarsely ground, and then mixed carefully with a little cold water, to prevent its running into lumps; water about 90° F. may then be added, till it is sufficiently diluted; and, lastly, a sufficient quantity of yeast. The whole is then to be allowed to ferment in a covered vessel, to which, however, the air can have access. Attention must be paid to the temperature; for if it exceed 77° F. the fermentation will be too rapid; if it be below 60°, the fermentation will cease.† The mean between these will generally be found most favourable. In this country it is the more common practice to mash the grain as for brewing malt liquors, and boil the wort. But in whichever way it be prepared, or if the *wash*, so the liquor intended for distillation is called, be made from molasses and water, due attention must be paid to the fermentation, that it be continued till the liquor grows fine, and pungent to the taste, which will generally be about the third day, but not so long as to permit the acetous fermentation to commence.

In this state the wash is to be committed to the still, of which, including the head, it should occupy at least three-fourths; and distilled with a gentle heat as long as any spirit comes over, which will be till about half the wash is consumed. The more slowly the distillation is conducted, the less will the product be contaminated with essential oil, and the less danger will there be of empyreuma. A great saving of time and fuel, however, may be obtained by making the still very broad and shallow, and contriving a free exit for the steam. This has been carried to such a pitch in Scotland, that a still measuring 43 gallons, and containing 16 gallons of wash, has been charged and worked no less than four hundred and eighty times in the space of twenty-four hours. This would be incredible, were it not established by unquestionable evidence. See Laboratory, article Still.

* The above wonderful rapidity of distillation has now ceased, since the excise duties have been levied on the quantity of spirit produced, and not, as formerly, by the size of the still. Hence, too, the spirit is probably improved in flavour.*

The first product, technically termed *low wine*, is again to be subjected to distillation, the latter portions of what comes over, called *faints*, being set apart to put into the wash still at some future operation. Thus a large portion of the watery part is left behind. This second product, termed *raw spirit*, being distilled again, is called *rectified spirit*. It is calculated, that a hundred gallons of malt or corn wash will not produce above twenty of spirit, containing 60 parts of alcohol to 50 of water; the same of cyder wash, 15 gallons; and of molasses wash, 22 gallons. The most spirituous wines of France, those of Languedoc, Guienne, and Rousillon, yield, according to Chaptal, from 20 to 25 gallons of excellent brandy from 100; but those of Burgundy and Champagne much less. Brisk wines, containing much carbonic acid, from the fermentation having been stopped at an early period, yield the least spirit.

The spirit thus obtained ought to be colourless, and free from any disagreeable flavour; and in this state it is fittest for pharmaceutical purposes, or the extraction of tinctures. But for ordinary sale something more is required. The brandy of France, which is most in esteem here, though perfectly colourless when first made, and often preserved so for use in that country, by being kept in glass or stone bottles, is put into new oak casks for exportation, whence it soon acquires an amber colour, a peculiar flavour, and something like an unctuosity of consistence. As it is not only prized for these qualities, but they are commonly deemed essential to it, the English distiller imitates by design these accidental qualities. The most obvious and natural method of doing this would be by impregnating a pure spirit with the extractive, resinous, and colouring matter of oak shavings; but other modes have been contrived. The dulcified spirit of nitre, as it is called, is commonly used to give the flavour; and catechu, or burnt sugar, to impart the desired colour. A French writer has recommended three ounces and a half of finely powered charcoal, and four ounces and a half of ground rice, to be digested for a fortnight in a quart of malt spirit.

The finest gin is said to be made in Holland, from a spirit drawn from wheat mixed with a third or fourth part of malted barley, and twice rectified over juniper berries; but in general, rye meal is used instead of wheat. They pay so much regard to the water employed, that many send vessels to fetch it on purpose from the Meuse; but all use the softest and clearest river water they can get. In England it is the common practice to add oil of turpentine, in the proportion of two ounces to ten gallons of raw spirit, with three handfuls of bay salt, and draw off till the faints begin to rise.

But corn or molasses spirit is flavoured likewise by a variety of aromatics, with or without sugar, to please different palates; all of which are included under the general technical term of *compounds* or *cordials*.

Other articles have been employed, though not generally, for the fabrication of spirit, as carrots and potatoes; and we are lately informed by Professor Proust, that from the fruit of the carob tree he has obtained good brandy in the proportion of a pint from five pounds of the dried fruit.

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† This is a mistake; fermentation will go on very slowly 10 degrees lower.

To obtain pure alcohol, different processes have been recommended; but the purest rectified spirit obtained as above described, being that which is least contaminated with foreign matter, should be employed. Rouelle recommends to draw off half the spirit in a water bath; to rectify this twice more, drawing off two-thirds each time; to add water to this alcohol, which will turn it milky by separating the essental oil remaining in it; to distil the spirit from this water; and finally rectify it by one more distillation.

Baumé sets apart the first running, when about a fourth is come over, and continues the distillation till he has drawn off about as much more, or till the liquor runs off milky. The last running he puts into the still again, and mixes the first half of what comes over with the preceding first product. This process is again repeated, and all the first products being mixed together, are distilled afresh. When about half the liquor is come over, this is to be set apart as pure alcohol.

Alcohol in this state, however, is not so pure as when, to use the language of the old chemists, it has been *dephlegmated*, or still further freed from water, by means of some alkaline salt. Boerhaave recommended, for this purpose, the muriate of soda, deprived of its water of crystallization by heat, and added hot to the spirit. But the subcarbonate of potash is preferable. About a third of the weight of the alcohol should be added to it in a glass vessel, well shaken, and then suffered to subside. The salt will be moistened by the water absorbed from the alcohol; which being decanted, more of the salt is to be added, and this is to be continued till the salt falls dry to the bottom of the vessel. The alcohol in this state will be reddened by a portion of the pure potash, which it will hold in solution, from which it must be freed by distillation in a water bath. Dry muriate of lime may be substituted advantageously for the alkali.

As alcohol is much lighter than water, its specific gravity is adopted as the test of its purity. Fourcroy considers it as rectified to the highest point when its specific gravity is 829, that of water being 1000; and perhaps this is nearly as far as it can be carried by the process of Rouelle or Baumé simply. Mr. Bories found the first measure that came over from twenty of spirit at 836 to be 820, at the temperature of 71° F. Sir Charles Blagden, by the addition of alkali, brought it to 813, at 60° F. Chaussier professes to have reduced it to 798; but he gives 998.35 as the specific gravity of water. Lowitz asserts, that he has obtained it at 791, by adding as much alkali as nearly to absorb the spirit; but the temperature is not indicated. In the shops it is about 835 or 840; according to the London College it should be 815.

It is by no means an easy undertaking to determine the strength or relative value of spirits, even with sufficient accuracy for commercial purposes. The following requisites must be obtained before this can be well done: the specific gravity of a certain number of mixtures of alcohol and water must be taken so near each other, as that the intermediate specific gravities may not perceptibly differ from those deduced from the supposition of a mere mixture of the fluids; the expansions of variations of specific gravity in these mixtures must be determined at different temperatures; some easy method must be contrived of determining the presence and quantity of saccharine or oleaginous matter which the spirit may hold in solution, and the effect of such solution on the specific gravity; and lastly, the specific gravity of the fluid must be ascertained by a proper floating instrument with a graduated stem, or set of weights; or, which may be more convenient, with both.

The strength of brandies in commerce is judged by the phial, or by burning. The phial proof consists in agitating the spirit in a bottle, and observing the form and magnitude of the bubbles that collect round the edge of the liquor, technically termed the *bead*, which are larger the stronger the spirit. These probably depend on the solution of resinous matter from the cask, which is taken up in greater quantities, the stronger the spirit. It is not difficult, however, to produce this appearance by various simple additions to weak spirit. The proof by burning is also fallacious; because the magnitude of the flame, and quantity of residue, in the same spirit, vary greatly with the form of the vessel it is burned in. If the vessel be kept cool, or suffered to become hot, if it be deeper or shallower, the results will not be the same in each case. It does not follow, however, but that manufacturers and others may in many instances receive considerable information from these signs, in circumstances exactly alike, and in the course of operations wherein it would be inconvenient to recur continually to experiments of specific gravity.

The importance of this object, as well for the purposes of revenue as of commerce, induced the British government to employ Dr. Blagden, now Sir Charles, to institute a very minute and accurate series of experiments. These may be considered as fundamental results; for which reason, I shall give a summary of them in this place, from the Philosophical Transactions for 1790.

The first object to which the experiments were directed was to ascertain the quantity and law resulting from the mutual penetration of water and spirit.

All bodies in general expand by heat; but the quantity of this expansion, as well as the law of its progression, is probably not the same in any two substances. In water and spirit they are remarkably different. The whole expansion of pure spirit from 30° to 100° of Fahrenheit's thermometer is not less than 1-25th of its whole bulk at 30°; whereas that of water, in the same interval, is only 1-145th of its bulk. The laws of their expansion are still more different than the quantities. If the expansion of quicksilver be, as usual, taken for the standard, (our thermometers being constructed with that fluid,) the expansion of spirit is, indeed, progressively increasing with respect to that standard, but not much so within the abovementioned interval; while water kept from freezing to 30°, which may easily be done, will absolutely contract as it is heated for ten or more degrees, that is, to 40° or 42° of the thermometer, and will then begin to expand as its heat is augmented, at first slowly, and afterward gradually more rapidly, so as to observe upon the whole a very increasing progression. Now, mixtures of these two substances will, as may be supposed, approach to the less or the greater of these progressions, according as they are compounded of more spirit or more water, while their total expansion will be greater, according as more spirit enters into their composition; but the exact quantity of the expansion, as well as law of the progression, in all of them, can be determined only by trials. These were, therefore, the two other principal objects to be ascertained by experiment.

The person engaged to make these experiments was Dr. Dollfuss, an ingenious Swiss gentleman then in London, who had distinguished himself by several publications on chemical subjects. As he could not conveniently get the quantity of spirit he wanted lighter than 825, at 60° F., he fixed upon this strength as the standard for alcohol.

These experiments of Dr. Dollfuss were repeated by Mr. Gilpin, clerk of the Royal Society; and as the deductions in this account will be taken chiefly from that last set of experiments, it is proper here to describe minutely the method observed by Mr. Gilpin in his operation. This naturally resolves itself into two parts: the way of making the mixtures, and the way of ascertaining their specific gravity.

1. The mixtures were made by weight, as the only accurate method of fixing the proportions. In fluids of such very unequal expansions by heat as water and alcohol, if measures had been employed, increasing or decreasing in regular proportions to each other, the proportions of the masses would have been sensibly irregular: now the latter was the object in view, namely, to determine the real quantity of spirit in any given mixture, abstracting the consideration of its temperature. Besides, if the proportions had been taken by measure, a different mixture should have been made at every different degree of heat. But the principal consideration was, that with a very nice balance, such as was employed on this occasion, quantities can be determined to much greater exactness by weight than by any practicable way of measurement. The proportions were therefore always taken by weight. A phial being provided of such a size as that it should be nearly full with the mixture, was made perfectly clean and dry, and being counterpoised, as much of the pure spirit as appeared necessary was poured into it. The weight of this spirit was then ascertained, and the weight of distilled water required to make a mixture of the intended proportions was calculated. This quantity of water was then added, with all the necessary care, the last portions being put in by means of a well-known instrument, which is composed of a small dish terminating in a tube drawn to a fine point: the top of the dish being covered with the thumb, the liquor in it is prevented from running out through the tube by the pressure of the atmosphere, but instantly begins to issue by drops, or a very small stream, upon raising the thumb. Water being thus introduced into the phial, till it exactly counterpoised the weight, which having been previously computed, was put into the opposite scale, the phial was shaken, and then well stopped with its glass stopple, over which leather was tied very tight, to prevent evaporation. No mixture was used till it had remained in the phial at least a month, for the full penetration to have taken place; and it was always well shaken before it was poured out to have its specific gravity tried.

2. There are two common methods of taking the specific gravity of fluids; one, by finding the weight which a solid body loses by being immersed in them; the other, by filling a convenient vessel with them, and ascertaining the increase of weight it acquires. In both cases a standard must have been previously taken, which is usually distilled water; namely, in the first method, by finding the weight lost by the solid body in the water; and in the second method, the weight of the

vessel filled with water. The latter was preferred, for the following reasons:—

When a ball of glass, which is the properest kind of solid body, is weighed in any spirituous or watery fluid, the adhesion of the fluid occasions some inaccuracy, and renders the balance comparatively sluggish. To what degree this effect proceeds is uncertain; but from some experiments made by Mr. Gilpin with that view, it appears to be very sensible. Moreover, in this method a large surface must be exposed to the air during the operation of weighing, which, especially in the higher temperatures, would give occasion to such an evaporation as to alter essentially the strength of the mixture. It seemed also as if the temperature of the fluid under trial could be determined more exactly in the method of filling a vessel, than in the other: for the fluid cannot well be stirred while the ball to be weighed remains immersed in it; and as some time must necessarily be spent in the weighing, the change of heat which takes place during that period will be unequal through the mass, and may occasion a sensible error. It is true, on the other hand, that in the method of filling a vessel, the temperature could not be ascertained with the utmost precision, because the neck of the vessel employed, containing about ten grains, was filled up to the mark with spirit not exactly of the same temperature, as will be explained presently: but this error, it is supposed, would by no means equal the other, and the utmost quantity of it may be estimated very nearly. Finally, it was much easier to bring the fluid to any given temperature when it was in a vessel to be weighed, than when it was to have a solid body weighed in it; because in the former case the quantity was smaller, and the vessel containing it more manageable, being readily heated with the hand or warm water, and cooled with cold water: and the very circumstance, that so much of the fluid was not required, proved a material convenience. The particular disadvantage in the method of weighing in a vessel, is the difficulty of filling it with extreme accuracy; but when the vessel is judiciously and neatly marked, the error of filling will, with due care, be exceedingly minute. By several repetitions of the same experiments, Mr. Gilpin seemed to bring it within the 1-15000th part of the whole weight.

The above-mentioned considerations induced Dr. Blagden, as well as the gentlemen employed in the experiments, to give the preference to weighing the fluid itself; and that was accordingly the method practised both by Dr. Dollfuss and Mr. Gilpin in their operations.

The vessel chosen as most convenient for the purpose was a hollow glass ball, terminating in a neck of small bore. That which Dr. Dollfuss used held 5800 grains of distilled water; but as the balance was so extremely accurate, it was thought expedient, upon Mr. Gilpin's repetition of the experiments, to use one of only 2965 grains capacity, as admitting the heat of any fluid contained in it to be more nicely determined. The ball of this vessel, which may be called the weighing bottle, measured about 2.8 inches in diameter, and was spherical, except a slight flattening on the part opposite to the neck, which served as a bottom for it to stand upon. Its neck was formed of a portion of a barometer tube, .25 of an inch in bore, and about 1½ inch long; it was perfectly cylindrical, and, on its outside, very near the middle of its length, a fine circle or ring was cut round it with a diamond, as the mark to which it was to be filled with the liquor. This mark was made by fixing the bottle in a lathe, and turning it round with great care, in contact with the diamond. The glass of this bottle was not very thick; it weighed 916 grains, and with its silver cap 936.

When the specific gravity of any liquor was to be taken by means of this bottle, the liquor was first brought nearly to the required temperature, and the bottle was filled with it up to the beginning of the neck only, that there might be room for shaking it. A very fine and sensible thermometer was then passed through the neck of the bottle into the contained liquor, which showed whether it was above or below the intended temperature. In the former case the bottle was brought into colder air, or even plunged for a moment into cold water; the thermometer in the mean time being frequently put into the contained liquor, till it was found to sink to the right point. In like manner, when the liquor was too cold, the bottle was brought into warmer air, immersed in warm water, or more commonly held between the hands, till upon repeated trials with the thermometer the just temperature was found. It will be understood, that during the course of this heating or cooling, the bottle was very frequently shaken between each immersion of the thermometer; and the top of the neck was kept covered, either with the finger, or a silver cap made on purpose, as constantly as possible. Hot water was used to raise the temperature only in heats of 80° and upwards, inferior heats being obtained by applying the hands to the bottle; when the hot water was employed, the ball of the bottle was plunged into it, and again quickly lifted out, with the necessary shaking interposed, as often as was necessary for communicating the required heat to the liquor; but care was taken to wipe the bottle dry after each immersion, before it was shaken, lest any adhering moisture might by accident get into it. The liquor having by these means been brought to the desired temperature; the next operation was to fill up the bottle exactly to the mark upon the neck, which was done with some of the same liquor, by means of a glass funnel with a very small bore. Mr. Gilpin endeavoured to get that portion of the liquor which was employed for this purpose, pretty nearly to the temperature of the liquor contained in the bottle; but as the whole quantity to be added never exceeded ten grains, a difference of ten degrees in the heat of that small quantity, which is more than it ever amounted to, would have occasioned an error of only 1-30th of a degree in the temperature of the mass. Enough of the liquor was put in to fill the neck rather above the mark, and the superfluous quantity was then absorbed to great nicety, by bringing into contact with it the fine point of a small roll of blotting paper. As the surface of the liquor in the neck would be always concave, the bottom or centre of this concavity was the part made to coincide with the mark round the glass; and in viewing it care was taken, that the near and opposite sides of the mark should appear exactly in the same line, by which means all parallax was avoided. A silver cap, which fitted tight, was then put upon the neck, to prevent evaporation; and the whole apparatus was in that state laid in the scale of the balance, to be weighed with all the exactness possible.

The spirit employed by Mr. Gilpin was furnished to him by Dr. Dollfuss, under whose inspection it had been rectified from rum supplied by government. Its specific gravity, at 60 degrees of heat, was .82514. It was first weighed pure, in the above-mentioned bottle, at every five degrees of heat, from 30 to 100 inclusively. Then mixtures were formed of it, and distilled water, in every proportion, from 1-20th of the water to equal parts of water and spirit; the quantity of water added being successively augmented, in the proportion of five grains to one hundred of the spirit; and these mixtures were also weighed in the bottle, like the pure spirit, at every five degrees of heat. The numbers hence resulting are delivered in the following table; where the first column shows the degrees of heat; the second gives the weight of the pure spirit contained in the bottle at those different degrees; the third gives the weight of a mixture in the proportions of 100 parts by weight of that spirit to 5 of water, and so on successively till the water is to the spirit as 100 to 5. They are the mean of three several experiments at least, as Mr. Gilpin always filled and weighed the bottle over again that number of times, if not oftener. The heat was taken at the even degree, as shown by the thermometer, without any allowance in the first instance, because the coincidence of the mercury with a division can be perceived more accurately than any fraction can be estimated; and the errors of the thermometers, if any, it was supposed would be less upon the grand divisions of 5 degrees than in any others. It must be observed, that Mr. Gilpin used the same mixture throughout all the different temperatures, heating it up from 30° to 100°; hence some small error in its strength may have been occssioned in the higher degrees, by more spirit evaporating than water: but this, it is believed, must have been trifling, and greater inconvenience would probably have resulted from interposing a fresh mixture.

The precise specific gravity of the pure spirit employed was .82514; but to avoid an inconvenient fraction, it is taken, in constructing the table of specific gravities, as .825 only, a proportional deduction being made from all the other numbers. Thus the following table gives the true specific gravity, at the different degrees of heat, of a pure rectified spirit, the specific gravity of which at 60° is .825, together with the specific gravities of different mixtures of it with water, at those different temperatures.

Real Specific Gravities at the different Temperatures.

Heat.	The pure spirit.	100 grains of spirit to 5 gr. of water	100 grains of spirit to 10 gr. of water	100 grains of spirit to 15 gr. of water	100 grains of spirit to 20 gr. of water	100 grains of spirit to 25 gr. of water	100 grains of spirit to 30 gr. of water	100 grains of spirit to 35 gr. of water	100 grains of spirit to 40 gr. of water	100 grains of spirit to 45 gr. of water	100 grains of spirit to 50 gr. of water
30°	·83896	·84995	·85957	·86825	·87585	·88282	·88921	·89511	·90054	.90558	·91023
35	83672	84769	85729	86587	87357	88059	88701	89294	89839	90345	90811
40	83445	84539	85507	86361	87134	87338	88481	89073	89617	90127	90596
45	83214	84310	85277	86131	86905	87613	88255	88849	89396	89909	90380
50	82977	84076	85042	85902	86676	87384	88030	88626	89174	89684	90160
55	82736	83834	84802	85664	86441	87150	87796	88393	88945	89458	89933
60	82500	83599	84568	85430	86208	86918	87569	88169	88720	89232	89707
65	82262	83362	84334	85193	85976	86686	87337	87938	88490	89006	89479
70	82023	83124	84092	84951	85736	86451	87105	87705	88254	88773	89252
75	81780	82878	83851	84710	85496	86212	86864	87466	88018	88538	89018
80	81530	82631	83603	84467	85248	85966	86622	87228	87776	88301	88781
85	81291	82396	83371	84243	85036	85757	86411	87021	87590	88120	88609
90	81044	82150	83126	84001	84797	85518	86172	86787	87360	87889	88376
95	80794	81900	82877	83753	84550	85272	85928	86542	87114	87654	88146
100	80548	81657	82639	83513	84038	85031	85688	86302	86879	87421	87915

Heat.	100 grains of spirit to 55 gr. of water	100 grains of spirit to 60 gr. of water	100 grains of spirit to 65 gr. of water	100 grains of spirit to 70 gr. of water	100 grains of spirit to 75 gr. of water	100 grains of spirit to 80 gr. of water	100 grains of spirit to 85 gr. of water	100 grains of spirit to 90 gr. of water	100 grains of spirit to 95 gr. of water	100 gr. of spirit to 100 gr. of water
30°	·91449	·91847	·92217	·92563	.92889	·93191	·93474	·93741	·93991	·94222
35	91241	91640	92009	92355	92680	92986	93274	93541	93790	94025
40	91026	91428	91799	92151	92476	92783	93072	93341	93592	93827
45	90812	91211	91584	91937	92264	92570	92859	93131	93382	93621
50	90596	90997	91370	91723	92051	92358	92647	92919	93177	93419
55	90367	90768	91144	91502	91837	92145	92436	92707	92963	93208
60	90144	90549	90927	91287	91622	91933	92225	92499	92758	93002
65	89920	90328	90707	91066	91400	91715	92010	92283	92546	92794
70	89695	90104	90484	90847	91181	91493	91793	92069	92333	92580
75	89464	89872	90252	90617	90952	91270	91569	91849	92111	92364
80	89225	89639	90021	90385	90723	91046	91340	91622	91891	92142
85	89043	89460	89843	90209	90558	90882	91186	91465	91729	91969
90	88817	89230	89617	89988	90342	90668	90967	91248	91511	91751
95	88588	89003	89390	89763	90119	90443	90747	91029	91290	91531
100	88357	88769	89158	89536	89889	90215	90522	90805	91066	91310

Heat.	95 grains of spirit to 100 gr. of water.	90 grains of spirit to 100 gr. of water.	85 grains of spirit to 100 gr. of water.	80 grains of spirit to 100 gr. of water.	75 grains of spirit to 100 gr. of water.	70 grains of spirit to 100 gr. of water.	65 grains of spirit to 100 gr. of water.	60 grains of spirit to 100 gr. of water.	55 grains of spirit to 100 gr. of water.	50 grains of spirit to 100 gr of water.
30°	.94447	.94675	.94920	.95173	.95429	.95681	.95944	.96209	.96470	.96719
35	94249	94484	94734	94988	95246	95502	95772	96048	96315	96579
40	94058	94295	94547	94802	95060	95328	95602	95879	96159	96434
45	93860	94096	94348	94605	94871	95143	95423	95705	95993	96280
50	93658	93897	94149	94414	94683	94958	95243	95534	95831	96126
55	93452	93696	93948	94213	94486	94767	95057	95357	95662	95966
60	93247	93493	93749	94018	94296	94579	94876	95181	95493	95804
65	93040	93285	93546	93822	94099	94388	94689	95000	95318	95635
70	92828	93076	93337	93616	93898	94193	94500	94813	95139	95469
75	92613	92865	93132	93413	93695	93989	94301	94623	94957	95292
80	92393	92646	92917	93201	93488	93785	94102	94431	94768	95111

Heat.	45 grains of spirit to 100 gr. of water.	40 grains of spirit to 100 gr. of water.	35 grains of spirit to 100 gr. of water.	30 grains of spirit to 100 gr. of water.	25 grains of spirit to 100 gr. of water.	20 grains of spirit to 100 gr. of water.	15 grains of spirit to 100 gr. of water.	10 grains of spirit to 100 gr. of water.	5 grains of spirit to 100 gr. of water.
30°	.96967	.97200	.97418	.97635	.97860	.98108	.98412	.98804	.99334
35	96840	97086	97319	97556	97801	98076	98397	98804	99344
40	96706	96967	97220	97472	97737	98033	98373	98795	99345
45	95563	96840	97110	97384	97666	97980	98338	98774	99338
50	96420	96708	96995	97284	97589	97920	98293	98745	99316
55	96272	96575	96877	97181	97500	97847	98239	98702	99284
60	96122	96437	96752	97074	97410	97771	98176	98654	99244
65	95962	96288	96620	96959	97309	97688	98106	98594	99194
70	95802	96143	96484	96836	97203	97596	98028	98527	99134
75	95638	95987	96344	96708	97086	97495	97943	98454	99066
80	95467	95826	96192	96568	96963	97385	97845	98367	98991

From this table, when the specific gravity of any spirituous liquor is ascertained, it will be easy to find the quantity of rectified spirit of the above-mentioned standard, contained in any given quantity of it, either by weight or measure.

Dr. Blagden concludes this part of the report with observing, that as the experiments were made with pure spirit and water, if any extraneous substances are contained in the liquor to be tried, the specific gravity in the tables will not give exactly the proportions of water and spirit in it. The substances likely to be found in spirituous liquors, where no fraud is suspected, are essential oils, sometimes empyreumatic, mucilaginous or extractive matter, and perhaps some saccharine matter. The effect of these, in the course of trade, seems to be hardly such as would be worth the cognizance of the excise, nor could it easily be reduced to certain rules. Essential and empyreumatic oils are nearly of the same specific gravity as spirit, in general rather lighter, and therefore, notwithstanding the mutual penetration, will probably make little change in the specific gravity of any spirituous liquor in which they are dissolved. The other substances are all heavier than spirit; the specific gravity of common gum being 1.482, and of sugar 1.606, according to the tables of M. Brisson. The effect of them therefore will be to make spirituous liquors appear less strong than they really are. An idea was once entertained of endeavouring to determine this matter with some precision; and accordingly Dr. Dollfuss evaporated 1000 grains of brandy, and the same quantity of rum, to dryness; the former left a residuum of 40 grains, the latter only of 8½ grains. The 40 grains of residuum from the brandy, dissolved again in a mixture of 100 of spirit, with 50 of water, increased its specific gravity .00041; hence the effect of this extraneous matter upon the specific gravity of the brandy containing it, would be to increase the fifth decimal by six nearly, equal to what would indicate in the above-mentioned mixture, about one-seventh of a grain of water more than the truth, to 100 of spirit; a quantity much too minute for the consideration of government.

* The strength of spirits is determined, according to the existing laws, by Sikes' hydrometer; but as many dealers use Dicas's, I shall describe it here, and the former under Distillation.

It consists of a light copper ball, terminating below with a ballast bottom, and above with a thin stem, divided into ten parts. The upper extremity of the stem is pointed, to receive the little brass poises, or discs, having each a hole in its centre. These poises are numbered 0, 10, 20, 30, &c. up to 350, which is the lightest of the series. The intermediate units are given by the subdivisions on the stem. A graduated ivory scale, with a sliding rule and thermometer, accompanies the hydrometer, to make the correction for temperature. The first thing in using this instrument is to plunge the thermometer into a glass cylinder containing the spirits to be tried. The sliding rule has then the degree of temperature indicated, moved opposite to zero. The hydrometer is now placed in the liquid, and such a poise is put on as to submerge a portion of the stem. The weight, added to the number on the stem, gives a sum, opposite to which on the scale we find a quantity, by which the particular spirit may exceed or fall short of proof. Thus, if it mark 20 under proof, it signifies that every 100 gallons of that spirit would require to have 20 gallons of water abstracted from it to bring it up to proof. If it mark 10 over proof, we learn that every 100 gallons contain too little water, by 10 gallons. When the thermometer degree of 60° is put opposite to zero, then the weights and value of the spirits have the following relations on this scale.

102.5 denotes	20 under proof
122.0	10
143.5	Proof
167.	10 over proof
193.	20
221.	30
251.	40
284.5	50
322.5	60
350.5	Alcohol.

There is, besides, an upper line on the scale, which exhibits the relation of spirit to water reckoned unity. Thus, above 10 per cent. over proof in the second line, we find in the upper line 8. From which we learn, that 8 of that spirit by bulk, will take 1 of water to bring it down to proof. At 60° Fahr. I find that 10 over proof on Dicas corresponds to

Specific gravity	0.9085
3½ over proof to	0.9169
Proof,	0.9218

Now, by Gilpin's tables this indicates a compound of 100 grains of alcohol 0.825, and 85 grains of water But by Lowitz's table in Crell's Annals, the above specific gravity corresponds to 48 alcohol of 0.791 at the temperature of 68°, united to 52 of water, and cooled down to 60. Equal weights of that strong alcohol and water, give, at 60°, a specific gravity of 0.9175. By the Act of Parliament of 1762, the specific gravity of proof was fixed at 0.916. It is at present to water as 12 to 13, or = 0.923. See Distillation.*

The most remarkable characteristic property of alcohol, is its solubility or combination in all proportions with water; a property possessed by no other combustible substance, *except the acetic spirit obtained by distilling the dry acetates.* When it is burned in a chimney which communicates with the worm-pipe of a distilling apparatus, the product, which is condensed, is found to consist of water, which exceeds the spirit in weight about one-eighth part; *or more accurately, 100 parts of alcohol, by combustion, yield 136 of water.* If alcohol be burned in closed vessels with vital air, the product is found to be water and carbonic acid. Whence it is inferred that alcohol consists of hydrogen, united either to carbonic acid or its acidifiable base; and that the oxygen uniting on the one part with the hydrogen, forms water; and on the other with the base of the carbonic acid, forms that acid.

* The most exact experiments on this subject are those recently made by M. de Saussure. The alcohol he used had, at 62.8°, a specific gravity of 0.8302; and by Richter's proportions, it consists of 13.8 water, and 86.2 of absolute alcohol. The vapour of alcohol was made to traverse a narrow porcelain tube ignited, from which the products passed along a glass tube about six feet in length, refrigerated by ice. A little charcoal was deposited in the porcelain, and a trace of oil in the glass tube. The resulting gas being analyzed in an exploding eudiometer, with oxygen, was found to resolve itself into carbonic acid and water. Three volumes of oxygen disappeared for every two volumes of carbonic acid produced; a proportion which obtains, in the analysis by oxygenation of olefiant gas. Now, as nothing resulted but a combustible gas of this peculiar constitution, and condensed water equal to $\frac{1022}{4464}$ of the original weight of the alcohol, we may conclude, that vapour of water and olefiant gas are the sole constituents of alcohol. Subtracting the 13.8 per cent. of water in the alcohol at the beginning of the experiment, the absolute alcohol of Richter will consist of 13.7 hydrogen, 51.98 carbon, and 34.32 oxygen. Hence M. Gay-Lussac infers, that alcohol, in vapour, is composed of one volume olefiant gas, and one volume of the vapour of water, condensed by chemical affinity into one volume.

The sp. gr. of olefiant gas is	0.97804
Of aqueous vapour is	0.62500
Sum =	1.60304
And alcoholic vapour is =	1.6133

These numbers approach nearly to those which would result from two prime equivalents of olefiant gas, combined with one of water; or ultimately, three of hydrogen, two of carbon, and one of oxygen.*

A considerable number of the uses of this fluid as a menstruum, will pass under our observation in the various articles of this work. The mutual action between alcohol and acids produces a light, volatile, and inflammable oil, called ether. See Ether. Pure alkalis unite with spirit of wine, and form alkaline tinctures. Few of the neutral salts unite with this fluid, except such as contain ammonia. The carbonated fixed alkalis are not soluble in it. From the strong attraction which exists between alcohol and water, it unites with this last in saline solutions, and in most cases precipitates the salt. This is a pleasing experiment, which never fails to surprise those who are unacquainted with chemical effects. If, for example, a saturated solution of nitre in water be taken, and an equal quantity of strong spirit of wine be poured upon it, the mixture will constitute a weaker spirit, which is incapable of holding the nitre in solution; it therefore falls to the bottom instantly, in the form of minute crystals.

The degrees of solubility of many neutral salts in alcohol have been ascertained by experiments made by Macquer, of which an account is published in the Memoirs of the Turin Academy. The alcohol he employed was carefully freed from superabundant water by repeated rectifications, without addition of any intermediate substance. The salts employed in his experiments were previously deprived of their water of crystallization by a careful drying. He poured into a matrass, upon each of the salts thus prepared, half an ounce of his alcohol, and set the matrass in a sand-bath. When the spirit began to boil, he filtrated it while it was hot, and left it to cool, that he might observe the crystallizations which took place. He then evaporated the spirit, and weighed the saline residuums. He repeated these experiments a second time, with this difference, that instead of evaporating the spirit in which the salt had been digested, he set fire to it in order to examine the phenomena which its flame might exhibit. The principal results of his experiments are subjoined.

Quantity of grains.	*Salts soluble in 200 grains of spirit.*	*Peculiar phenomena of the flame.*
4	Nitrate of potash	Flame larger, higher, more ardent, yellow, and luminous.
5	Muriate of potash	Large, ardent, yellow, and luminous.
0	Sulphate of soda	Considerably red.
15	Nitrate of soda	Yellow, luminous, detonating.
0	Muriate of soda	Larger, more ardent, and reddish.
0	Sulphate of ammonia	None.
108	Nitrate of ammonia	Whiter, more luminous.
24	Muriate of ammonia	None.
288	Nitrate of lime	Larger, more luminous, red and decrepitating.
288	Muriate of lime	Like that of the calcareous nitre.
84	Nitrate of silver	None.
204	Muriate of mercury	Large, yellow, luminous and decrepitating.
4	Nitrate of iron	Red and decrepitating.
36	Muriate of iron	More white, luminous and sparkling.
48	Nitrate of copper	More white, luminous and green, much smoke. The saline residuum became black and burnt.
48	Muriate of copper	Fine green, white, and red fulgurations.

Macquer accompanies the relation of his experiments with many judicious reflections, not easily capable of abridgment.

* The alcohol he employed in the above experiments had a specific gravity of 0.840. In analytical researches, alcohol affords frequently a valuable agent for separating salts from each other. We shall therefore introduce the following additional table, derived chiefly from the experiments of Wenzel;—

100 parts of alcohol dissolve of

		Temp.	
Nitrate of	Cobalt at	54.5°	100 parts
	Copper	54.5	100
	Alumina	54.5	100
	Lime		125
	Magnesia	180.5	290
Muriate of	Zinc	54.5	100
	Alumina	54.5	100
	Magnesia	180.5	547
	Iron	180.5	100
	Copper	180.5	100
Acetate of	Lead	154.5	100

At the boiling point, 100 parts of alcohol dissolve of muriate of lime 100 parts

Nitrate of ammonia,	89
Corrosive sublimate,	88.8
Succinic acid, -	74.0 parts
Acetate of soda, -	46.5
Nitrate of silver, -	41.7
Refined sugar, -	24.6
Boracic acid, -	20.0
Nitrate of soda, -	9.6
Acetate of copper,	7.5
Muriate of ammonia,	7.1
Superarseniate of potash,	3.75
Oxalate of potash, -	2.92
Nitrate of potash, -	2.08
Muriate of potash,	2.08
Arseniate of soda, -	1.58
Arsenious acid, -	1.25
Tartrate of potash,	0.42

It appears from the experiments of Kirwan, that dried muriate of magnesia dissolves more abundantly in strong than in weak alcohol. 100 parts of specific gravity 0.900, dissolve 21.25; of 0.848, 23.75; of 0.834, 36.25; and of 0.817, 50 parts. The same holds to a more limited extent with acetate of lime; 2.4 grains being soluble in 100 of the first alcohol, and 4.88 in 100 of the last. The other salts which he tried dissolved more sparingly in the stronger than in the weaker alcohol. The temperature of the spirit was generally 60°.

All deliquescent salts are soluble in alcohol. Alcohol holding the strontitic salts in solution, gives a flame of a rich purple. The cupreous salts and boracic acid give a green; the soluble calcareous, a reddish; the barytic, a yellowish. For the effect of other salts on the colour of the flame, see a preceding table.

The alcohol of 0.825 has been subjected to a cold of — 91° without congealing. But Mr. Hutton has given, in the Edinburgh Encyclopædia, article Cold, an account of his having succeeded in solidifying it by a cold of — 110°. The alcohol he employed had a density of 0.798 at 60°. His process has been kept secret. The boiling point of alcohol of 0.825 is 176°, Alcohol of 0.810 boils at 173.5°. For the force of its vapour at different temperatures, and its specific heat, see VAPOUR.

M. Gay-Lussac having shown that this liquid is a compound of olefiant gas and water, potassium ought to disengage from it, hydrogen and olefiant gas. In the absolute alcohol of Richter there is no water, independent of that which is essential to its constitution. See FERMENTATION.

When chlorine is made to pass through alcohol in a Woulfe's apparatus, there is a mutual action. Water, an oily looking substance, muriatic acid, a little carbonic acid, and carbonaceous matter, are the products. This oily substance does not redden turnsole, though its analysis by heat shows it to contain muriatic acid. It is white, denser than water, has a cooling taste analogous to mint, and a peculiar, but not ethereous odour. It is very soluble in alcohol, but scarcely in water. The strongest alkalis hardly operate on it.

It was at one time maintained, that alcohol did not exist in wines, but was generated and evolved by the heat of distillation. On this subject M. Gay-Lussac made some decisive experiments. He agitated wine with litharge in fine powder, till the liquid became as limpid as water, and then saturated it with subcarbonate of potash. The alcohol immediately separated and floated on the top. He distilled another portion of wine *in vacuo*, at 59° Fahr. a temperature considerably below that of fermentation. Alcohol came over. Mr. Brande proved the same position by saturating wine with subacetate of lead, and adding potash.

MM. Adam and Duportal have substituted for the redistillations used in converting wine or beer into alcohol, a single process of great elegance. From the capital of the still a tube is led into a large copper recipient. This is joined by a second tube, to a second recipient, and so on through a series of four vessels, arranged like a Woulfe's apparatus. The last vessel communicates with the worm of the first refrigeratory. This, the body of the still and the two recipients nearest it, are charged with the wine or fermented liquor. When ebullition takes place in the still, the vapour issuing from it communicates soon the boiling temperature to the liquor in the two recipients. From these the volatilized alcohol will rise and pass into the third vessel, which is empty. After communicating a certain heat to it, a portion of the finer or less condensable spirit will pass into the fourth, and thence, in a little, into the worm of the first refrigeratory. The wine round the worm will likewise acquire heat, but more slowly. The vapour that in that event may pass uncondensed through the first worm, is conducted into a second, surrounded with cold water. Whenever the still is worked off, it is replenished by a stop-cock from the nearest recipient, which, in its turn, is filled from the second, and the second from the first worm tub. It is evident, from this arrangement, that by keeping the 3d and 4th recipients at a certain temperature, we may cause alcohol, of any degree of lightness, to form directly at the remote extremity of the apparatus. The utmost economy of fuel and time is also secured, and a better flavoured spirit is obtained. The *arrière gout* of bad spirit can scarcely be destroyed by infusion with charcoal and redistillation. In this mode of operating, the taste and smell are excellent, from the first. Several stills on the above principle have been constructed at Glasgow for the West India distillers, and have been found extremely advantageous. The excise laws do not permit their employment in the home trade.*

If sulphur in sublimation meet with the vapour of alcohol, a very small portion combines with it, which communicates a hydrosulphurous smell to the fluid. The increased surface of the two substances appears to favour the combination. It had been supposed, that this was the only way in which they could be united; but M. Favre has lately asserted, that, having digested two drams of flowers of sulphur in an ounce of alcohol, over a gentle fire not sufficient to make it boil, for twelve hours, he obtained a solution that gave twenty-three grains of precipitate. A similar mixture left to stand for a month in a place exposed to the solar rays, afforded sixteen grains of precipitate; and another, from which the light was excluded, gave thirteen grains. If alcohol be boiled with one-fourth of its weight of sulphur for an hour, and filtered hot, a small quantity of minute crystals will be deposited on cooling; and the clear fluid will assume an opaline hue on being diluted with an equal quantity of water, in which state it will pass the filter, nor will any sediment be deposited for several hours. The alcohol used in the last-mentioned experiment did not exceed .840.

Phosphorus is sparingly soluble in alcohol, but in greater quantity by heat than in cold. The addition of water to this solution affords an opaque milky fluid, which gradually becomes clear by the subsidence of the phosphorus.

Earths seem to have scarcely any action upon alcohol. Quick-lime, however, produces some alteration in this fluid, by changing its flavour and rendering it of a yellow colour. A small portion is probably taken up.

Soaps are dissolved with great facility in alcohol, with which they combine more readily than with water. None of the metals, or their oxides, are acted upon by this fluid. Resins, essential oils, camphor, bitumen, and various other substances, are dissolved with great facility in alcohol, from which they may be precipitated by the addition of water. From its property of dissolving resins, it becomes the menstruum of one class of varnishes. See Varnish.

Camphor is not only extremely soluble in alcohol, but assists the solution of resins in it. Fixed oils, when rendered drying by metallic oxides, are soluble in it, as well as when combined with alkalis.

Wax, spermaceti, biliary calculi, urea, and all the animal substances of a resinous nature, are soluble in alcohol; but it curdles milk, coagulates albumen, and hardens the muscular fibre and coagulum of the blood.

The uses of alcohol are various. As a solvent of resinous substances and essential oils, it is employed both in pharmacy and by the perfumer. When diluted with an equal quantity of water, constituting what is called proof spirit, it is used for extracting tinctures from vegetable and other substances, the alcohol dissolving the resinous parts, and the water the gummy. From giving a steady heat without smoke when burnt in a lamp, it was formerly much employed to keep water boiling on the tea-table. In thermometers for measuring great degrees of cold, it is preferable to mercury, as we cannot bring it to freeze. It is in common use for preserving many anatomical preparations, and certain subjects of natural history; but to some it is injurious, the molluscæ for instance, the calcareous covering of which it in time corrodes. It is of considerable use too in chemical analysis, as appears under the different articles to which it is applicable.

From the great expansive power of alcohol, it has been made a question, whether it might not be applied with advantage in the working of steam engines. From a series of experiments made by Betancourt, it appears, that the steam of alcohol has, in all cases of equal temperature, more than double the force of that of water; and that the steam of alcohol at 174° F. is equal to that of water at 212°: thus there is a considerable diminution of the consumption of fuel, and where this is so expensive as to be an object of great importance, by contriving the machinery so as to prevent the alcohol from being lost, it may possibly at some future time be used with advantage, if some other fluid of great expansive power, and inferior price, be not found more economical.

It was observed at the beginning of this article, that alcohol might be decomposed by transmission through a red-hot tube: it is also decomposable by the strong acids, and thus affords that remarkable product, Ether and Oleum Vini.

Ale. See Beer.

Alembic, *or* Still. This part of chemical apparatus, used for distilling or separating volatile products, by first raising them by heat, and then condensing them into the liquid state by cold, is of extensive use in a variety of operations. It is described under the article Laboratory.

Alembroth Salt. Corrosive muriate of mercury is rendered much more soluble in water, by the addition of muriate of ammonia. From this solution crystals are separated by cooling, which were called sal alembroth by the earlier chemists, and appeared to consist of ammonia, muriatic acid, and mercury.

Algaroth (Powder of). Among the numerous preparations which the alchemical researches into the nature of antimony have afforded, the powder of algaroth is one. When butter of antimony is thrown into water, it is not totally dissolved; but part of the metallic oxide falls down in the form of a white powder, which is the powder of algaroth. It is violently purgative and emetic in small doses of three or four grains. See Antimony.

Alkahest. The pretended universal solvent, or menstruum, of the ancient chemists. Kunckel has very well shown the absurdity of searching for a universal solvent, by asking, "If it dissolve all substances, in what vessels can it be contained?"

Alkalescent. Any substance in which alkaline properties are beginning to be developed, or to predominate, is termed alkalescent. The only alkali usually observed to be produced by spontaneous decomposition is the volatile; and from their tendency to produce this, some species of vegetables, particularly the cruciform, are styled alkalescent, as are some animal substances. See Fermentation (Putrid).

* **Alkali.** A term derived from kali the Arabic name of a plant, from the ashes of which one species of alkaline substance can be extracted. Alkalis may be defined, those bodies which combine with acids, so as to neutralize or impair their activity, and produce salts. Acidity and alkalinity are therefore two correlative terms of one species of combination. When Lavoisier introduced oxygen as the acidifying principle, Morveau proposed hydrogen as the alkalifying principle, from its being a constituent of volatile alkali or ammonia. But the splendid discovery by Sir H. Davy, of the metallic bases of potash and soda, and of their conversion into alkalis, by combination with oxygen, has banished for ever that hypothetical conceit. It is the mode in which the constituents are combined, rather than the nature of the constituents themselves, which gives rise to the acid or alkaline condition. Some metals, combined with oxygen in one proportion, produce a body possessed of alkaline properties, in another proportion of acid properties. And on the other hand, ammonia and prussic acid prove that both the alkaline and acid conditions can exist independent of oxygen. These observations by generalizing our notions of acids and alkalis, have rendered the definitions of them very imperfect. The difficulty of tracing a limit between the acids and alkalis is still increased, when we find a body sometimes performing the functions of an acid, sometimes of an alkali. Nor can we diminish this difficulty by having recourse to the beautiful law discovered by Sir H. Davy, that oxygen and acids go to the positive pole, and hydrogen, alkalis, and inflammable bases to the negative pole. We cannot in fact give the name of acid to all the bodies which go to the first of these poles, and that of alkali to those that go to the second; and if we wished to define the alkalis by bringing into view their electric energy, it would be necessary to compare them with the electric energy which is opposite to them. Thus we are always reduced to define alkalinity by the property which it has of saturating acidity, because alkalinity and acidity are two correlative and inseparable terms. M. Gay-Lussac conceives the alkalinity which the metallic oxides enjoy to be the result of two opposite properties, the alkalifying property of the metal, and the acidifying of oxygen, modified both by the combination and by the proportions.

The alkalis may be arranged into three classes: 1st, Those which consist of a metallic basis combined with oxygen. These are three in number, potash, soda and lithia. 2d, That which contains no oxygen, viz. ammonia. 3d, Those containing oxygen, hydrogen, and carbon. In this class we have aconita, atropia, brucia, cicuta, datura, delphia, hyosciama, morphia, strychnia, and perhaps some other *truly vegetable* alkalis. The order of vegetable alkalis may be as numerous as that of vegetable acids. The earths, lime, barytes, and strontites were enrolled among the alkalis by Fourcroy; but they have been kept apart by other systematic writers, and are called alkaline earths.

Besides neutralizing acidity, and thereby giving birth to salts, the first four alkalis have the following properties:

1st, They change the purple colour of many vegetables to a green, the reds to a purple, and the yellows to a brown. If the purple have been reddened by acid, alkalis restore the purple.

2d, They possess this power on vegetable colours *after* being saturated with carbonic acid, by which criterion they are distinguishable from the alkaline earths.

3d, They have an acrid and urinous taste.

4th, They are powerful solvents or corrosives of animal matter; with which, as well as with oils in general, they combine, so as to produce neutrality.

5th, They are decomposed, or volatilized, at a strong red heat.

6th, They combine with water in every proportion, and also largely with alcohol.

7th, They continue to be soluble in water when neutralized with carbonic acid; while the alkaline earths thus become insoluble.

It is needless to detail at length Dr. Murray's speculations on alkalinity. They seem to flow from a partial view of chemical phenomena. According to him, either oxygen or hydrogen may generate alkalinity, but the combination of both principles is necessary to give this condition its utmost energy. "Thus the class of alkalis will exhibit the same relations as the class of acids. Some are compounds of a base with oxygen; such are the greater number of the metallic oxides, and probably of the earths. Ammonia is a compound of a base with hydrogen. Potash, soda, barytes, strontites, and probably lime, are compounds of bases with oxygen and hydrogen; and these last, like the analogous order among the acids, possess the highest power." Now, surely, perfectly dry and caustic barytes, lime, and strontites, as well as the dry potash and soda obtained by Gay-Lussac and Thenard, are not inferior in alkaline power to the same bodies after they are slacked or combined with water. 100 parts of lime destitute of hydrogen, that is, pure oxide of calcium, neutralize 78 parts of carbonic acid. But 132 parts of Dr. Murray's *strongest* lime, that is the hydrate, are required to produce the same alkafine effect. If we ignite nitrate of barytes, we obtain, as is well known, a perfectly dry barytes, or protoxide of barium; but if we ignite crystallized barytes, we obtain the same alkaline earth combined with a prime equivalent of water. These two different states of barytes were demonstrated by M. Berthollet in an excellent paper published in the 2d volume of the Memoires D'Arcueil, so far back as 1809. "The first barytes," (that from crystallized barytes), says he, "presents all the characters of a combination; it is engaged with a substance which *diminishes* its action on other bodies, which renders it more fusible, and which gives it by fusion the appearance of glass. This substance is nothing else but water; but in fact, by adding a little water to the second barytes (that from ignited nitrate), and by urging it at the fire, we give it the properties of the first." Page 47. 100 parts of barytes void of hydrogen, or dry barytes, neutralize 28½ of dry carbonic acid. Whereas 111⅔ parts of the hydrate, or what Dr. Murray has styled the most energetic, are required to produce the same effect. In fact, it is not hydrogen which combines with the pure barytic earth, but hydrogen and oxygen in the state of water. The proof of this is, that when carbonic acid and that hydrate unite, the exact quantity of water is disengaged. The protoxide of barium, or pure barytes, has never been combined with hydrogen by any chemist.*

Alkali (Phlogisticated, *or* Prussian.) When a fixed alkali is ignited with bullock's blood, or other animal substances, and lixiviated, it is found to be in a great measure saturated with the prussic acid: from the theories formerly adopted respecting this combination, it was distinguished by the name of phlogisticated alkali. See Acid (Prussic.)

Alkali (Volatile.) See Ammonia.

* **Alkalimeter.** The name first given by M. Descroizilles to an instrument or measure of his graduation, for determining the quantity of alkali in commercial potash and soda, by the quantity of dilute sulphuric acid of a known strength which a certain weight of them could neutralize. His method was unnecessarily operose. A much simpler, and very accurate mode, was exhibited by Dr. Ure before the Linen Board of Dublin in June 1816, and soon afterwards submitted in manuscript to Dr. Henry, who has since then expunged the description of M. Descroizilles' alkalimeter from his valuable elements, and substituted one on Dr. Ure's principle. More recently Dr. Ure has been occupied in completing the arrangement of an instrument for giving increased facility and dispatch to chemical analysis in general. It will apply to alkalis, acids, earths, metals, &c. He hopes to be able, very soon, to submit its construction and performance to the tribunal of the public. Meanwhile directions will be given in this work under the individual alkalis, for ascertaining the quality of commercial specimens.*

Alkanet. The alkanet plant is a kind of bugloss, which is a native of the warmer parts of Europe, and cultivated in some of our gardens. The greatest quantities are raised in Germany and France, particularly about Montpelier, whence we are chiefly supplied with the roots. These are of a superior quality to such as are raised in England. This root imparts an elegant deep red colour to pure alcohol, to oils, to wax, and to all unctuous substances. The aqueous tincture is of a dull brownish colour; as is likewise the spirituous tincture when inspissated to the consistence of an extract. The principal use of alkanet root is, that of colouring oils, unguents, and lip-salves. Wax tinged with it, and applied on warm marble, stains it of a flesh colour, which sinks deep into the stone; as the spirituous tincture gives it a deep red stain.†

As the colour of this root is confined to the bark, and the small roots have more bark in proportion to their bulk than the great ones, these also afford most colour.

* **Allanite.** A mineral first recognized as a distinct species by Mr. Allan, of Edinburgh, to whose accurate knowledge, and splendid collection, the science of mineralogy has been so much indebted in Scotland. Its analysis and description, by Dr. Thomson, were published in the 6th volume of the Edinburgh Ph. Trans. M. Giesecke found it in a granite rock in West Greenland. It is massive and of a brownish black colour. External lustre, dull; internal, shining and resinous—fracture small conchoidal—opaque—greenish gray streak—scratches glass and hornblende—brittle—spec. grav. 3.5 to 4.0. Froths and melts imperfectly before the

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† On making an infusion of alkanet roots in alcohol, I was surprised to find the colour a deep blue, instead of being red. Remembering that the alcohol had stood over an alkali, I added some acid to the blue infusion. It became instantly red; and the same colour appeared to be produced originally, when the roots were steeped in pure alcohol. I am surprised, that I have not met with any account of habitudes so interesting, and which acquire additional value, when contrasted with those of litmus and other vegetable colours, originally blue. These, reddened by an acid, are restored by an alkali; while alkanet, made blue by alkalis, is restored by acids.

blow-pipe, into a black scoria. It consists in 100 parts, of silica 35.4, oxide of cerium 33.9, oxide of iron 25.4, lime 9.2, alumina 4.1, and moisture 4.0. It has been also found crystallized in four, six, or eight-sided prisms. It closely resembles gadolinite, but may be distinguished, from the thin fragments of the latter being translucent on the edges, and of a fine green colour, whereas those of the former are commonly opaque and of a yellowish brown. The ores of cerium analyzed by Berzelius, under the name of cerin, approach very closely in their composition to allanite.*

* **Allochroite.** A massive opaque mineral of a grayish, yellowish, or reddish colour. Quartz scratches it, but it strikes fire with steel. It has externally, a glistening, and internally, a glimmering lustre. Its fracture is uneven, and its fragments are translucent on the edges: sp. gr. 3.5 to 3.6. It melts before the blow-pipe into a black opaque enamel. Vauquelin's analysis is the following: Silica 35, lime 30.5, oxide of iron 17, alumina 8, carbonate of lime 6, oxide of manganese 3.5. M. Brongniart says it is absolutely infusible without addition, and that it requires a flux as phosphate of soda or ammonia. With these it passes through a beautiful gradation of colours. It is covered at first with a species of enamel, which becomes on cooling reddish yellow, then greenish, and lastly of a dirty yellowish white. He represents it as pretty difficult to break. It was found by M. Dandrada in the iron mine of Virums, near Drammen in Norway. It is accompanied by carbonate of lime, protoxide of iron, and sometimes brown garnets.*

* **Allophane.** A mineral of a blue, and sometimes a green or brown colour, which occurs massive, or in imitative shapes. Lustre vitreous; fracture imperfectly conchoidal; transparent or translucent on the edges. Moderately hard, but very brittle. Sp. gr. 1.89. Composition, silica 21.92, alumina 32.2, lime 0.73, sulphate of lime 0.52, carbonate of copper 3.06, hydrate of iron 0.27, water 41.3. *Stromeyer.* It gelatinizes in acids: It is found in a bed of ironshot limestone in graywacke slate, in the forest of Thuringia. It was called Riemannite.*

Allay, or Alloy. Where any precious metal is mixed with another of less value, the assayers call the latter the alloy, and do not in general consider it in any other point of view than as debasing or diminishing the value of the precious metal. Philosophical chemists have availed themselves of this term to distinguish all metallic compounds in general. Thus brass is called an alloy of copper and zinc; bell metal an alloy of copper and tin.

* Every alloy is distinguished by the metal which predominates in its composition, or which gives it its value. Thus English jewellery trinkets are ranked under alloys of gold, though most of them deserve to be placed under the head of copper. When mercury is one of the component metals, the alloy is called amalgam. Thus we have an amalgam of gold, silver, tin, &c. Since there are about 30 different permanent metals, independent of those evanescent ones that constitute the bases of the alkalis and earths, there ought to be about 870 different species of binary alloy. But only 132 species have been hitherto made and examined. Some metals have so little affinity for others, that as yet no compound of them has been effected, whatever pains have been taken. Most of these obstacles to alloying, arise from the difference in fusibility and volatility. Yet a few metals whose melting point is nearly the same, refuse to unite. It is obvious that two bodies will not combine, unless their affinity or reciprocal attraction, be stronger than the cohesive attraction of their individual particles. To overcome this cohesion of the solid bodies, and render affinity predominant, they must be penetrated by caloric. If one be very difficult of fusion, and the other very volatile, they will not unite unless the reciprocal attraction be exceedingly strong. But if their degree of fusibility be almost the same, they are easily placed in the circumstances most favourable for making an alloy. If we are therefore far from knowing all the binary alloys which are possible, we are still further removed from knowing all the triple, quadruple, &c. which may exist. It must be confessed, moreover, that this department of chemistry has been imperfectly cultivated.

Besides, alloys are not, as far as we know, definitely regulated like oxides in the proportions of their component parts. 100 parts of mercury will combine with 4, or 8, parts of oxygen, to form two distinct oxides, the black and the red; but with no greater, less, or intermediate proportions. But 100 parts of mercury will unite with 1, 2, 3, or with any quantity up to a 100 or 1000, of tin or lead. The alloys have the closest relations in their physical properties with the metals. They are all solid at the temperature of the atmosphere, except some amalgams; they possess metallic lustre, even when reduced to a coarse powder; are completely opaque, and more or less dense, according to the metals which compose them; are excellent conductors of electricity; crystallize more or less perfectly; some are brittle, others ductile and malleable; some have a peculiar odour; several are very sonorous and elastic. When an alloy consists of metals differently fusible, it is usually malleable while cold, but brittle while hot; as is exemplified in brass.

The density of an alloy is sometimes greater, sometimes less than the mean density of its components, showing that, at the instant of their union, a diminution, or augmentation of volume takes place. The relation between the expansion of the separate metals, and that of their alloys, has been investigated only in a very few cases. Alloys containing a volatile metal are decomposed, in whole or in part, at a strong heat. This happens with those of arsenic, mercury, tellurium and zinc. Those that consist of two differently fusible metals, may often be decomposed, by exposing them to a temperature capable of melting only one of them. This operation is called eliquation. It is practised on the great scale to extract silver from copper. The argentiferous copper is melted with 3½ times its weight of lead; and the triple alloy is exposed to a sufficient heat. The lead carries off the silver in its fusion, and leaves the copper under the form of a spongy lump. The silver is afterwards recovered from the lead by another operation.

Some alloys oxidize more readily by heat and air, than when the metals are separately treated. Thus 3 of lead, and 1 of tin, at a dull red, burn visibly, and are almost instantly oxidized. Each by itself in the same circumstances, would oxidize slowly, and without the disengagement of light.

The formation of an alloy must be regulated by the nature of the particular metals; to which therefore we refer.

The degree of affinity between metals may be in some measure estimated by the greater or less facility with which, when of different degrees of fusibility or volatility, they unite, or with which they can after union be separated by heat. The greater or less tendency to separate into different proportional alloys, by long continued fusion, may also give some information on this subject. Mr. Hatchett remarked, in his admirable researches on metallic alloys, that gold made standard with the usual precautions by silver, copper, lead, antimony, &c. and then cast into vertical bars, was by no means a uniform compound; but that the top of the bar, corresponding to the metal at the bottom of the crucible, contained the larger proportion of gold. Hence, for thorough combination, two red-hot crucibles should be employed; and the liquefied metals should be alternately poured from the one into the other. And to prevent unnecessary oxidizement by exposure to air, the crucibles should contain, besides the metal, a mixture of common salt and pounded charcoal. The melted alloy should also be occasionally stirred up with a rod of pottery.

The most direct evidence of a chemical change having taken place in the two metals by combination, is when the alloy melts at a much lower temperature than the fusing points of its components. Iron which is nearly infusible, when alloyed with gold, acquires almost the fusibility of this metal. Tin and lead form solder, an alloy more fusible than either of its components; but the triple compound of tin, lead, and bismuth, is most remarkable on this account. The analogy is here strong, with the increase of solubility, which salts acquire by mixture, as is exemplified in the uncrystallizable residue of saline solutions, or mother waters, as they are called. Sometimes two metals will not directly unite, which yet, by the intervention of a third, are made to combine. This happens with mercury and iron, as has been shown by Messrs. Aikin, who effected this difficult amalgamation by previously uniting the iron to tin or zinc.

The tenacity of alloys is generally, though not always, inferior to the mean of the separate metals. One part of lead will destroy the compactness and tenacity of a thousand of gold. Brass, made with a small proportion of zinc, is more ductile than copper itself; but when one-third of zinc enters into its composition, it becomes brittle.

In common cases, the specific gravity affords a good criterion whereby to judge of the proportion in an alloy, consisting of two metals of different densities. But a very fallacious rule has been given in some respectable works, for comparing the specific gravity that should result from given quantities of two metals of known densities alloyed together, supposing no chemical penetration or expansion of volume to take place. Thus it has been taught, that if gold and copper be united in equal weights, the computed or mathematical specific gravity of the alloy is the arithmetical mean of the two specific gravities. This error was pointed out by me in a paper published in the 7th number of the Journal of Science and the Arts; and the correct rule was at the same time given. The details belong to the article Specific Gravity; but the rule merits a place here. The specific gravity of the alloy is found by dividing the sum of the weights by the sum of the volumes, compared to water, reckoned unity. Or in another form, the rule may be stated thus: Multiply the sum of the weights into the product of the two specific gravities for a numerator, and multiply each specific gravity into the weight of the other body, and add the two products together for a denominator. The quotient obtained by dividing the numerator by the denominator, is the true *computed* mean specific gravity; and that found by experiment, being compared with it, will shew whether expansion or condensation of volume has attended the chemical combination. Gold having a specific gravity of 19.36, and copper of 8.87, being alloyed in equal weights, give on the fallacious rule of the arithmetical mean of the densities,

$$\frac{19.36 + 8.87}{2} = 14.11;$$

whereas the rightly calculated mean specific gravity is only 12.16. It is evident that by comparing the former number with chemical experiment, we should be led to infer a prodigious condensation of volume beyond what really occurs.

A circumstance was observed by Mr. Hatchett to influence the density of metals, which *a priori* might be thought unimportant. When a bar of gold was cast in a vertical position, the density of the metal at the lower end of the bar was greater than that of the top, in the proportion of 17.364 to 17.035. Are we to infer that melted metal is a compressible fluid, or rather, that particles passing into the solid state under pressure, exert their cohesive attraction with adventitious strength? Under the title *metal*, a tabular view of metallic combinations will be found, and under that of the particular metal, the requisite information about its alloys.

Alluvial Formations, in geology, are recent deposites in valleys or in plains, of the *detritus* of the neighbouring mountains. Gravel, loam, clay, sand, brown coal, wood coal, bog iron ore, and calc tuff, compose the alluvial deposites. The gravel and sand sometimes contain gold and tin, if the ores exist in the adjoining mountains. Petrified wood and animal skeletons are found in the alluvial clays and sand.*

Almonds. Almonds consist chiefly of an oil of the nature of fat oils, together with farinaceous matter. The oil is so plentiful, and so loosely combined or mixed with the other principles, that it is obtained by simple pressure, and part of it may be squeezed out with the fingers. Five pounds and a half have yielded one pound six ounces of oil by cold expression, and three quarters of a pound more on heating them. There are two kinds of almonds, the sweet and bitter. The bitter almonds yield an oil as tasteless as that of the other, all the bitter matter remaining in the cake after the expression. Great part of the bitter matter dissolves by digestion, both in watery and spirituous liquors; and part arises with both in distillation. Rember obtained from them 1-3d of watery extract, and 3-32ds of spirituous. Bitter almonds are poisonous to birds, and to some animals. A water distilled from them, when made of a certain degree of strength, has been found from experiment to be poisonous to brutes; and there are instances of cordial spirits impregnated with them being poisonous to men. It seems, indeed, that the vegetable principle of bitterness in almonds and the kernels of other fruits, is destructive to animal life, when separated by distillation from the oil and farinaceous matter. The distilled water from laurel leaves appears to be of this nature, and its poisonous effects are well known.

Sweet almonds are made into an emulsion by trituration with water, which on standing separates a thick cream floating on the top. The emulsion may be curdled by heat, or the addition of alcohol or acids. The whey contains gum, extractive matter, and sugar, according to Professor Proust; and the curd, when washed and dried, yields oil by expression, and afterwards by distillation the same products as cheese. The whey is a good diluent.

* Prussic or hydrocyanic acid is the deleterious ingredient in bitter almonds. The best remedy after emetics is a combination of sulphate of iron with bicarbonate of potash.*

Aloes. This is a bitter juice, extracted from the leaves of a plant of the same name. Three sorts of aloes are distinguished in the shops by the names of aloe socotrina, aloe hepatica, and aloe caballina. The first denomination, which is applied to the purest kind, is taken from the island of Zocotora; the second, or next in quality, is called hepatica, from its liver colour; and the third, caballina, from the use of this species being confined to horses. These kinds of aloes are said to differ only in purity, though, from the difference of their flavours, it is probable that they may be obtained in some instances from different species of the same plant. It is certain, however, that the different kinds are all prepared at Morviedro in Spain, from the same leaves of the common aloe. Deep incisions are made in the leaves, from which the juice is suffered to flow; and this, after decantation from its sediment, and inspissation in the sun, is exposed to sale in leathern bags by the name of socotrine aloes. An additional quantity of juice is obtained by pressure from the leaves; and this, when decanted from its sediment and dried, is the hepatic aloes. And lastly, a portion of juice is obtained by strong pressure of the leaves, and is mixed with the dregs of the two preceding kinds to form the caballine aloes. The first kind is said to contain much less resin. The principal characters of good aloes are these: it must be glossy, not very black, but brown; when rubbed or cut, of a yellow colour; compact, but easy to break; easily soluble; of an unpleasant peculiar smell, which cannot be described, and an extremely bitter taste.

Aloes appears to be an intimate combination of gummy resinous matter, so well blended together, that watery or spirituous solvents, separately applied, dissolve the greater part of both. It is not determined whether there be any difference in the medical properties of these solutions. Both are purgative, as is likewise the aloes in substance; and, if used too freely, are apt to prove heating, and produce hemorrhoidal complaints.

* Braconnot imagines he has detected in aloes a peculiar principle, similar to the *bitter resinous* which Vauquelin has found in many febrifuge barks. The recent juice of the leaves absorbs oxygen, and becomes a fine reddish purple pigment.*

Aludel. The process of sublimation differs from distillation in the nature of its product, which, instead of becoming condensed in a fluid, assumes the solid state, and the form of the receivers may of course be very different. The receivers for sublimates are of the nature of chimneys, in which the elastic products are condensed, and adhere to their internal surface. It is evident that the head of an alembic will serve very well to receive and condense such sublimates as are not very volatile. The earlier chemists, whose notions of simplicity were not always the most perfect, thought proper to use a number of similar heads, one above the other, communicating in succession by means of a perforation in the superior part of each, which received the neck of the capital immediately above it. These heads, differing in no respect from the usual heads of alembics, excepting in their having no nose or beak, and in the other circumstances here mentioned, were called aludels. They are seldom now to be seen in chemical laboratories, because the operations of this art may be performed with greater simplicity of instruments, provided attention be paid to the heat and other circumstances.

* **Alum.** See **Alumina**, Sulphate of.*

* **Alum-Earth.** A massive mineral, of a blackish brown colour, a dull lustre, an earthy and somewhat slaty fracture, sectile, and rather soft. By Klaproth's analysis it contains, charcoal 19.65, silica 40, alumina 16, oxide of iron 6.4, sulphur 2.84, sulphates of lime and potash, each 1,5, sulphate of iron 1.8, magnesia and muriate of potash 0.5, and water 10.75.

* **Alum-Slate.** 1. Common. This mineral occurs both massive and in insulated balls, of a grayish black colour, dull lustre, straight slaty fracture, tabular fragments, streak coloured like itself; though soft it is not very brittle. Effloresces, acquiring the taste of alum.

2. Glossy Alum-slate. A massive mineral of a bluish black colour. The rents display a variety of lively purple tints. It has a semi-metallic lustre in the fracture, which is straight, slaty, or undulating. There is a soft variety of it approaching in appearance to slate clay. By exposure to air, its thickness is prodigiously augmented by the formation of a saline efflorescence, which separates its thinnest plates. These afterwards exfoliate in brittle sections, causing entire disintegration.*

* **Alumina.** One of the primitive earths, which, as constituting the plastic principle of all clays, loams and boles, was called argil or the argillaceous earth; but now, as being obtained in greatest purity from alum, is styled alumina. It was deemed elementary matter till Sir H. Davy's celebrated electro-chemical researches led to the belief of its being, like barytes and lime, a metallic oxide.

The purest native alumina is found in the oriental gems, the sapphire and ruby. They consist of nothing but this earth, and a small portion of colouring matter. The native porcelain clays or kaolins, however white and soft, can never be regarded as pure alumina. They usually contain fully half their weight of silica, and frequently other earths. To obtain pure alumina we dissolve alum in 20 times its weight of water, and add to it a little of the solution of ~~carbonate of soda~~, to throw down any iron which may be present. We then drop the supernatant liquid into a quantity of the water of ammonia, taking care not to add so much of the aluminous solution as will saturate the ammonia. The volatile alkali unites with the sulphuric acid of the alum, and the earthy basis of the latter is separated in a white spongy precipitate. This must be thrown on a filter, washed, or edulcorated as the old chemists expressed it, by repeated affusions of water, and then dried. Or if an alum, made with ammonia instead of potash, as is the case with some French alums, can be got, simple ignition dissipates its acid and alkaline constituents, leaving pure alumina.

Alumina prepared by the first process is white, pulverulent, soft to the touch, adheres to the tongue, forms a smooth paste without grittiness in the mouth, insipid, inodorous, produces no change in vegetable colours, insoluble in water, but mixes with it readily in every proportion, and retains a small quantity with considerable force; is infusible in the strongest heat of a furnace, experiencing merely a condensation of volume and consequent hardness, but it is in small quantities melted by the oxy-hydrogen blowpipe. Its specific gravity is 2.000, in the state of powder, but by ignition it is augmented.

Every analogy leads to the belief that alumina contains a peculiar metal, which may be called aluminum. The first evidences obtained of this position are presented in Sir H. Davy's researches. Iron negatively electrified by a very high power being fused in contact with pure alumina, formed a globule whiter than pure iron, which effervesced slowly in water, becoming covered with a white powder. The solution of this in muriatic acid, decomposed by an alkali, afforded alumina and oxide of iron. By passing potassium in vapour through alumina heated to whiteness, the greatest part of the potassium became converted into potash, which formed a coherent mass with that part of the alumina not decompounded; and in this mass there were numerous gray particles, having the metallic lustre, and which became white when heated in the air, and which slowly effervesced in water. In a similar experiment made by the same illustrious chemist, a strong red heat only being applied to the alumina, a mass was obtained, which took fire spontaneously by exposure to air, and which effervesced violently in water. This mass was probably an alloy of aluminum and potassium. The conversion of potassium into its deutoxide, dry potash, by alumina, proves the presence of oxygen in the latter. When regarded as an oxide, Sir H. Davy estimates its oxygen and basis to be to one another as 15 to 33; or as 10 to 22. The prime equivalent of alumina would thus appear to be $1.0 + 2.2 = 3.2$.

But Berzelius's analysis of sulphate of alumina seems to indicate 2.136 as the quantity of the earth which combines with 5. of the acid. Hence aluminum will come to be represented by $2.136 - 1. = 1.136$. But we shall presently show that his analysis, both of alum and sulphate of alumina, may be reconciled to Sir. H. Davy's equivalent prime $= 3.2$. That of aluminum will become of course 2.2.

Alumina which has lost its plasticity by ignition, recovers it by being dissolved in an acid or alkaline menstruum, and then precipitated. In this state it is called a hydrate, for when dried in a steam-heat it retains much water; and therefore resembles in composition wavellite, a beautiful mineral, consisting almost entirely of alumina, with about 28 per cent of water. Alumina is widely diffused in nature. It is a constituent of every soil, and of almost every rock. It is the basis of porcelain, pottery, bricks, and crucibles. Its affinity for vegetable colouring matter, is made use of in the preparation of lakes, and in the arts of dyeing and calico printing. Native combinations of alumina, constitute the fuller's earth, ochres, boles, pipe-clays, &c.*

* ALUMINA, (SALTS of).

These salts have the following general characters:

1. Most of them are very soluble in water, and their solutions have a sweetish acerb taste.

2. Ammonia throws down their earthy base, even though they have been previously acidulated with muriatic acid.

3. At a strong red heat they give out a portion of their acid.

4. Phosphate of ammonia gives a white precipitate.

5. Hydriodate of potash produces a flocculent precipitate of a white colour, passing into a permanent yellow.

6. They are not affected by oxalate of ammonia, tartaric acid, ferroprussiate of potash, or tincture of galls; by the first two tests they are distinguished from yttria, and by the last two from that earth and glucina.

7. If bisulphate of potash be added to a solution of an aluminous salt, moderately concentrated, octahedral crystals of alum will form.

Acetate of Alumina. By digesting strong acetic acid on newly precipitated alumina, this saline combination can be directly formed. Vinegar of ordinary strength scarcely acts on the earth. But the salt is seldom made in this way. It is prepared in large quantities for the calico printers, by decomposing alum with acetate of lead; or more economically with aqueous acetate of lime, having a specific gravity of about 1.050; a gallon of which, equivalent to nearly half a pound avoirdupois of dry acetic acid, is employed for every 2½ lb. of alum. A sulphate of lime is formed by complex affinity, which precipitates, and an acetate of alumina floats above. The above proportion of alum is much beyond the equivalent quantity; and the specific gravity of the liquid is consequently raised by the excess of salt. It is usually 1.080. By careful evaporation capillary crystals are formed, which readily deliquesce. M. Gay-Lussac made some curious observations on the solutions of this salt. Even when made with cold saturated solutions of alum and acetate of lead, and consequently but little concentrated, it becomes turbid when heated to 122° Fahr.; and at a boiling heat a precipitate falls of about one-half of the whole salt. On cooling, it is redissolved. This decomposition by heat, which would be prejudicial to the calico printer, is prevented by the excess of alum, which is properly used in actual practice. M. Gay-Lussac thinks this phenomenon has considerable analogy, with the coagulation of albumen by heat; the particles of the water, and of the solid matter, being carried by the heat out of their sphere of activity, separate. It is probably a subacetate which falls down, as well as that which is obtained by drying the crystals. Wenzel's analysis of acetate of alumina gives 73.81 acid to 26.19 base in 100 parts. If we suppose it to consist, like the sulphate, of three primes of acid to two of alumina, we shall have for its equivalent proportions, 20 of dry acid + 6.4 earth, or 75.8 + 24.2 = 100. As alum contains, in round numbers, about 1-9th of earthy base, 8 oz. of real acetic acid present in the gallon of the redistilled pyrolignous, would require about 2⅓ lbs. of alum, for exact decomposition. The excess employed is found to be useful.

The affinity between the constituents of this salt is very feeble. Hence the attraction of cotton fibre for alumina, aided by a moderate heat, is sufficient to decompose it.

The following salts of alumina are insoluble in water:—Arseniate, borate, phosphate, tungstate, mellate, saclactate, lithate, malate, camphorate. The oxalate is uncrystallizable. It consists of 56 acid and water, and 44 alumina. The tartrate does not crystallize. But the tartrate of potash and alumina is remarkable, according to Thenard, for yielding no precipitate, either by alkalis or alkaline carbonates. The supergallate crystallizes. There seems to be no dry carbonate. A supernitrate exists very difficult to crystallize. Its specific gravity is 1.645. A moderate heat drives off the acid. The muriate is easily made by digesting muriatic acid on gelatinous alumina. It is colourless, astringent, deliquescent, uncrystallizable, reddens turnsole, and forms a gelatinous mass by evaporation. Alcohol dissolves at 60° half its weight of this salt. A dull red heat separates the acid from the alumina. Its composition is, according to Bucholz, 29.8 acid, 30.0 base, 40.2 water, in 100 parts.

Sulphate of alumina exists under several modifications. The simple sulphate is easily made, by digesting sulphuric acid on pure clay. The salt thus formed crystallizes in thin soft plates, having a pearly lustre. It has an astringent taste, and is so soluble in water as to crystallize with difficulty. When moderately heated the water escapes, and, at a higher temperature, the acid. Berzelius has chosen this salt for the purpose of determining the equivalent of alumina. He considers the dry sulphate as a compound of 100 parts of sulphuric acid with 42.722 earth. This makes the equivalent 21.361, oxygen being reckoned 10, if we consider it a compound of a prime proportion of each. But if we regard it as consisting of 3 of acid and 2 of base, we shall have 32.0 for the prime equivalent of alumina. The reason for preferring this number will appear in treating of the next salt.*

* Alum. This important salt has been the object of innumerable researches, both with regard to its fabrication and composition.* It is produced, but in a very small quantity, in the native state; and this is mixed with heterogeneous matters. It effloresces in various forms upon ores during calcination, but it seldom occurs crystallized. The greater part of this salt is factitious, being extracted from various minerals called alum ores, such as, 1. Sulphuretted clay. This constitutes the purest of all aluminous ores, namely, that of la Tolfa, near Civita Vecchia, in Italy. It is white, compact, and as hard as indurated clay, whence it is called *petra aluminaris*. It is tasteless and mealy; one hundred parts of this ore contain above forty of sulphur and fifty of clay, a small quantity of potash, and a little iron. Bergmann says it contains forty-three of sulphur in one hundred, thirty-five of clay, and twenty two of siliceous earth. This ore is first torrefied to acidify the sulphur, which then acts on the clay, and forms the alum.

2. The pyritaceous clay, which is found at Schwemsal, in Saxony, at the depth of ten or twelve feet. It is a black and hard, but brittle substance, consisting of clay, pyrites, and bitumen It is exposed to the air for two years; by which means the pyrites are decomposed, and the alum is formed. The alum ores of Hesse and Liege are of this kind; but they are first torrefied, which is said to be a disadvantageous method.

3. The schistus aluminaris contains a variable proportion of petroleum and pyrites intimately mixed with it. When the last are in a very large quantity, this ore is rejected as containing too much iron. Professor Bergmann very properly suggested, that by adding a proportion of clay, this ore may turn out advantageously for producing alum. But if the petrol be considerable, it must be torrefied. The mines of Becket in Normandy, and those of Whitby in Yorkshire, are of this species.

4. Volcanic aluminous ore. Such is that of Solfaterra near Naples. It is in the form of a white saline earth, after it has effloresced in the air; or else it is in a stony form.

5. Bituminous alum ore is called shale, and is in the form of a shistus, impregnated with so much oily matter, or bitumen, as to be inflammable. It is found in Swe-

den, and also in the coal mines at Whitehaven, and elsewhere.

Chaptal has fabricated alum on a large scale from its component parts. For this purpose he constructed a chamber 91 feet long, 48 wide, and 31 high in the middle. The walls are of common masonry, lined with a pretty thick coating of plaster. The floor is paved with bricks, bedded in a mixture of raw and burnt clay; and this pavement is covered with another, the joints of which overlap those of the first, and instead of mortar the bricks are joined with a cement of equal parts of pitch, turpentine, and wax, which, after having been boiled till it ceases to swell, is used hot. The roof is of wood, but the beams are very close together, and grooved lengthwise, the intermediate space being filled up by planks fitted into the grooves, so that the whole is put together without a nail. Lastly, the whole of the inside is covered with three or four successive coatings of the cement above mentioned, the first being laid on as hot as possible; and the outside of the wooden roof was varnished in the same manner. The purest and whitest clay being made into a paste with water, and formed into balls half a foot in diameter, these are calcined in a furnace, broken to pieces, and a stratum of the fragments laid on the floor. A due proportion of sulphur is then ignited in the chamber, in the same manner as for the fabrication of sulphuric acid; and the fragments of burnt clay, imbibing this as it forms, begin after a few days to crack and open, and exhibit an efflorescence of sulphate of alumina. When the earth has completely effloresced, it is taken out of the chamber, exposed for some time in an open shed, that it may be the more intimately penetrated by the acid, and is then lixiviated and crystallized in the usual manner. The cement answers the purpose of lead on this occasion very effectually, and accordingly to M. Chaptal, costs no more than lead would at three farthings a-pound.

Curaudau has lately recommended a process for making alum without evaporation. One hundred parts of clay and five of muriate of soda are kneaded into a paste with water, and formed into loaves. With these a reverberatory furnace is filled, and a brisk fire is kept up for two hours. Being powdered, and put into a sound cask, one-fourth of their weight of sulphuric acid is poured over them by degrees, stirring the mixture well at each addition. As soon as the muriatic gas is dissipated, a quantity of water equal to the acid is added, and the mixture stirred as before. When the heat is abated, a little more water is poured in, and this is repeated till eight or ten times as much water as there was acid is added. When the whole has settled, the clear liquor is drawn off into leaden vessels, and a quantity of water equal to this liquor is poured on the sediment. The two liquors being mixed, a solution of potash is added to them, the alkali in which is equal to one-fourth of the weight of the sulphuric acid. Sulphate of potash may be used, but twice as much of this as of the alkali is necessary. After a certain time the liquor by cooling affords crystals of alum equal to three times the weight of the acid used. It is refined by dissolving it in the smallest possible quantity of boiling water. The residue may be washed with more water, to be employed in lixiviating a fresh portion of the ingredients.

As the mother water still contains alum, with sulphate of iron very much oxided, it is well adapted to the fabrication of prussian blue. This mode of making alum is particularly advantageous to the manufacturers of prussian blue, as they may calcine their clay at the same time with their animal matters, without additional expense; they will have no need in this case to add potash; and the presence of iron, instead of being injurious, will be very useful. If they wished to make alum for sale, they might use the solution of sulphate of potash, arising from the washing of their prussian blue, instead of water, to dissolve the combination of alumina and sulphuric acid.

The residuums of distillers of aquafortis are applicable to the same purposes, as they contain the alumina and potash requisite, and only require to be reduced to powder, sprinkled with sulphuric acid, and lixiviated with water, in the manner directed above. The mother waters of these alums are also useful in the fabrication of prussian blue. As the residuum of aquafortis contains an over-proportion of potash, it will be found of advantage to add an eighth of its weight of clay calcined as above.

* The most extensive alum manufactory in Great Britain is at Hurlett, near Paisley, on the estate of the Earl of Glasgow. The next in magnitude is at Whitby; of whose state and processes an instructive account was published by Mr. Winter, in the 25th volume of Nicholson's Journal. The stratum of aluminous schistus is about 29 miles in width, and it is covered by strata of alluvial soil, sandstone, ironstone, shell, and clay. The alum schist is generally found disposed in horizontal laminæ. The upper part of the rock is the most abundant in sulphur; so that a cubic yard taken from the top of the stratum, is 5 times more valuable than the same bulk, 100 feet below.

If a quantity of the schistus be laid in a heap and moistened with sea water, it will take fire spontaneously, and will continue to burn till the whole inflammable matter be consumed. Its colour is bluish gray. Its specific gravity is 2.48. It imparts a bituminous principle to alcohol. Fused with an alkali, muriatic acid precipitates a large proportion of silex.

The expense of digging and removing to a distance of 200 yards one cubic yard of the schistose rock, is about sixpence-halfpenny. A man can earn from 2s. 6d. to 3s. a-day. The rock, broken into small pieces, is laid on a horizontal bed of fuel, composed of brushwood, &c. When about 4 feet in height of the rock is piled on, fire is set to the bottom, and fresh rock continually poured upon the pile. This is continued until the calcined heap be raised to the height of 90 or 100 feet. Its horizontal area has also been progressively extended at the same time, till it forms a great bed nearly 200 feet square, having about 100,000 yards of solid measurement. The rapidity of the combustion is allayed by plastering up the crevices with small schist moistened. Notwithstanding of this precaution, a great deal of sulphuric or sulphurous acid is dissipated. 130 tons of calcined schist produce on an average 1 ton of alum. This result has been deducedfrom an average of 150,000 tons.

The calcined mineral is digested in water contained in pits that usually contain about 60 cubic yards. The liquid is drawn off into cisterns, and afterwards pumped up again upon fresh calcined *mine*. This is repeated until the specific gravity becomes 1.15. The half exhausted schist is then covered with water, to take up the whole soluble matter. The strong liquor is drawn off into settling cisterns, where the sulphate of lime, iron, and earth, are deposited. At some works the liquid is boiled, which aids its purification. It is then run into leaden pans, 10 feet long, 4 feet 9 inches wide, 2 feet 2 inches deep at the one end, and 2 feet 8 inches at the other. This slope makes them be easily emptied. Here the liquor is concentrated at a boiling heat. Every morning the pans are emptied into a settling cistern, and a solution of muriate of potash, either pretty pure from the manufacturer, or crude and compound from the soap-boiler, is added. The quantity of muriate necessary is determined by a previous experiment in a basin, and is regulated for the workmen by the hydrometer. By this addition, the pan liquor, which had acquired a specific gravity of 1.4 or 1.5, is reduced to 1.35. After being allowed to settle for two hours, it is run off into the coolers to be crystallized. At a greater sp. gravity than 1.35, the liquor, instead of crystallizing, would, when it cools, present us with a solid magma, resembling grease. Urine is occasionally added, to bring it down to the proper density.

After standing 4 days, the mother waters are drained off, to be pumped into the pans on the succeeding day. The crystals of alum are washed in a tub, and drained. They are then put into a lead pan, with as much water as will make a saturated solution at the boiling point. Whenever this is effected, the solution is run off into casks. At the end of 10 or 16 days, the casks are unhooped and taken asunder. The alum is found exteriorily in a solid cake, but in the interior cavity, in large pyramidal crystals, consisting of octahedrons, inserted successively into one another. This last process is called roching. Mr. Winter says, that 22 tons of muriate of potash will produce 100 tons of alum, to which 31 tons of the black ashes of the soap-boiler, or 73 of kelp, are equivalent. Where much iron exists in the alum ore, the alkaline muriate, by its decomposition, gives birth to an uncrystallizable muriate of iron. The alum manufactured in the preceding mode is a supersulphate of alumina and potash. There is another alum which exactly resembles it. This is a supersulphate of alumina and ammonia. Both crystallize in regular octahedrons, formed by two four-sided pyramids joined base to base. Alum has an astringent sweetish taste. Its sp. gravity is about 1.71. It reddens the vegetable blues. It is soluble in 16 parts of water at 60°, and in ¾ths of its weight at 212.° It effloresces superficially on exposure to air, but the interior remains long unchanged. Its water of crystallization is sufficient at a gentle heat to fuse it. If the heat be increased it froths up, and loses fully 45 per cent. of its weight in water. The spongy residue is called burnt or calcined alum, and is used by surgeons as a mild escharotic. A violent heat separates a great portion of its acid.

Alum thus was analyzed by Berzelius: 1st, 20 parts (grammes) of pure alum lost by the heat of a spirit lamp 9 parts, which gives 45 per cent. of water. The dry salt was dissolved in water, and its acid precipitated by muriate of barytes; the sulphate of which, obtained after ignition, weighed 20 parts; indicating in 100 parts 34.3 of dry sulphuric acid. 2d, Ten parts of alum were dissolved in water, and digested with an excess of ammonia. Alumina, well washed and burnt, equivalent to 10.67 per cent. was obtained. In another experiment, 10.86 per cent. resulted. 3d, Ten parts of alum dissolved in water, were digested with carbonate of strontites, till the earth was completely separated.

The sulphate of potash, after ignition, weighed 1.815, corresponding to 0.981 potash, or in 100 parts to 9.81.

Alum, therefore, consists of

Sulphuric acid,	34.33
Alumina,	10.86
Potash,	9.81
Water,	45.00
	100.00

or, Sulphate of alumina,	36.85
Sulphate of potash,	18.15
Water, - - - -	45.00
	100.00

Thenard's analysis, Ann. de Chimie, vol. 59. or Nicholson's Journal, vol. 18. coincides perfectly with that of Berzelius in the product of sulphate of barytes. From 490 parts of alum, he obtained 490 of the ignited barytic salt; but the alumina was in greater proportion, equal to 12.54 per cent, and the sulphate of potash less, or 15.7 in 100 parts.

Dr. Thomson considers it as a compound of 3 atoms sulphate of alumina, 1 atom sulphate of potash, and 23 atoms water, as follows:

Sulphate of alumina,	36.70
Sulphate of potash,	18.88
Water, - - - -	44.42
	100.00

But Vauquelin, in his last analysis, found 48.58 water; and by Thenard's statement there are indicated

34.23	dry acid,
7.14	potash,
12.54	alumina,
46.09	water,
100.00	

It deserves to be remarked, that the analysis of Professor Berzelius agrees with the supposition that alum contains,

4 sulphuric acid,	= 20.0	34.36
2 alumina,	= 6.4	11.00
1 potash,	= 6.0	10.30
23 water,	= 25.8	44.34
	58.2	100.00

If we rectify Vauquelin's erroneous estimate of the sulphate of barytes, his analysis will also coincide with the above. Alum, therefore, differs from the simple sulphate of alumina previously described, which consisted of 3 prime equivalents of acid, and 2 of earth, merely by its assumption of a prime of sulphate of potash. It is probable that all the aluminous salts have a similar constitution. It is to be observed, moreover, that the number 34.36 resulting from the theoretic proportions, is, according to Gilbert's remarks on the essay of Berzelius, the just representation of the dry acid in 100 of sulphate of barytes, by a corrected analysis, which makes the prime of barytes 9.57.

Should ammonia be suspected in alum, it may be detected, and its quantity estimated, by mixing quicklime with the saline solution, and exposing the mixture to heat in a retort, connected with a Woulfe's apparatus. The water of ammonia being afterwards saturated with an acid, and evaporated to a dry salt, will indicate the quantity of pure ammonia in the alum. A variety of alum, containing both potash and ammonia, may also be found. This will occur where urine has been used, as well as muriate of potash, in its fabrication. If any of these bisulphates of alumina and potash be acted on in a watery solution, by gelatinous alumina, a neutral triple salt is formed, which precipitates in a nearly insoluble state.

When alum in powder is mixed with flour or sugar, and calcined, it forms the pyrophorus of Homberg.

Mr. Winter first mentioned, that another variety of alum can be made with *soda*, instead of potash. This salt, which crystallizes in octahedrons, has been also made with pure muriate of soda, and bisulphate of alumina, at the laboratory of Hurlett, by Mr. W. Wilson. It is extremely difficult to form, and effloresces like the sulphate of soda.

The only injurious contamination of alum is sulphate of iron. It is detected by ferroprussiate of potash. To get rid of it cheaply, M. Thenard recommended dissolving the alum in boiling water, and agitating the solution with rods as it cools. The salt is thus reduced to a fine granular powder, which being washed two or three times with cold water, and drained, yields a perfectly pure alum. For a very advantageous mode of concentrating alum liquors, as well as those of other salts, on the great scale, see EVAPORATION.

Oxymuriate of alumina, or the chloride, has been proposed by Mr. Wilson of Dublin as preferable to solution of chlorine, for discharging the turkey-red dye. He prepares it by adding to a solution of oxymuriate of lime, at a sp. gravity of 1.060, a solution of alum of the sp. grav. 1.100, as long as any precipitate falls. The clear liquid is to be drawn off from the precipitate, and kept in close vessels. He says that it does not injure the cloth, nor annoy the the workmen, like the liquor of uncombined chlorine.—*Ann. of Phil.* vol. viii.*

Alum is used in large quantities in many manufactories. When added to tallow, it renders it harder. Printer's cushions, and the blocks used in the calico manufactory, are rubbed with burnt alum to remove any greasiness, which might prevent the ink or colour from sticking. Wood sufficiently soaked in a solution of alum does not easily take fire; and the same is true of paper impregnated with it, which is fitter to keep gunpowder, as it also excludes moisture. Paper impregnated with alum is useful in whitening silver, and silvering brass without heat. Alum mixed in milk helps the separation of its butter. If added in a very small quantity to turbid water, in a few minutes it renders it perfectly limpid, without any bad taste or quality; while the sulphuric acid imparts to it a very sensible acidity, and does not precipitate so soon, or so well, the opaque earthy mixtures that render it turbid, as I have often tried. It is used in making pyrophorus, in tanning and many other manufactories, particularly in the art of dyeing, in which it is of the greatest and most important use, by cleansing and opening the pores on the surface of the substance to be dyed, rendering it fit for receiving the colouring particles, (by which the alum is generally decomposed,) and at the same time making the colour fixed. Crayons generally consist of the earth of alum, finely powdered, and tinged for the purpose. In medicine it is employed as an astringent.

* **Aluminite.** A mineral of a snow-white colour, dull, opaque, and having a fine earthy fracture. It has a glistening streak. It is found in kidney-shaped pieces, which are soft to the touch, and adhere slightly to the tongue. Sp. gravity, 1.67.

It consists of Sulphuric acid,	19.25
Alumina,	32.50
Water,	47,00
Silica, lime, and oxide of iron,	1.25
	100.00

It may be represented very exactly by

2	primes of acid,	10	=	20
5	alumina,	16	=	32
21	water,	23.6	=	47.2
	Foreign matter,	0.4	=	0.8
		50.0		100,0

The conversion of the above into alum is easily explained. When the three primes composing bisulphate of potash come into play, they displace precisely three primes (or atoms) of alumina. Two additional primes of water are also introduced at the same time, by the strong affinity of the bisulphate for the particles of that liquid.

The above alum ore is found chiefly in the alluvial strata round Halle in Saxony.*

* **Amadou.** It is a variety of the *boletus igniarius*, found on old ash and other trees. It is boiled in water to extract its soluble parts, then dried, and beat with a mallet to loosen its texture. It has now the appearance of very spongy doe-skin leather. It is lastly impregnated with a solution of nitre, and dried when it is called spunk, or German tinder; a substance much used on the continent for lighting fire, either from the collision of flint and steel, or from the sudden condensation of air in the atmospheric pyrophorus.*

Amalgam. This name is applied to the combinations of mercury with other metallic substances. See **Mercury.**

Amber is a hard, brittle, tasteless substance, sometimes perfectly transparent, but mostly semi-transparent or opaque, and of a glossy surface: it is found of all colours, but chiefly yellow or orange, and often contains leaves or insects; its specific gravity is from 1.065 to 1.100; its fracture is even, smooth, and glossy; it is capable of a fine polish, and becomes electric by friction; when rubbed or heated, it gives a peculiar agreeable smell, particularly when it melts, that is at 550° of Fahrenheit, but it then loses its transparency; projected on burning coals, it burns with a whitish flame, and a whitish yellow smoke, but gives very little soot, and leaves brownish ashes; it is insoluble in water and alcohol, though the latter, when highly rectified, extracts a reddish colour from it; but it is soluble in the sulphuric acid, which then acquires a reddish purple colour, and is precipitable from it by water; no other acid dissolves it, nor is it soluble in essential or expressed oils, without some decomposition and long digestion; but pure alkali dissolves it. By distillation it affords a small quantity of water, with a little acetous acid, an oil, and a peculiar acid. See **Acid (Succinic).** The oil rises at first colourless; but, as the heat increases, becomes brown, thick, and empyreumatic. The oil may be rectified by successive distillations, or it may be obtained very light and limpid at once, if it be put into a glass alembic with water, as the elder Rouelle directs, and distilled at a heat not greater than 212° Fahr. It requires to be kept in stone bottles, however, to retain this state; for in glass vessels it becomes brown by the action of light.

Amber is met with plentifully in regular mines in some parts of Prussia. The upper surface is composed of sand, under which is a stratum of loam, and under this a bed of wood, partly entire, but chiefly mouldered or changed into a bituminous substance. Under the wood is a stratum of sulphuric or rather aluminous mineral, in which the amber is found. Strong sulphureous exhalations are often perceived in the pits.

* Detached pieces are also found occasionally on the sea-coast in various coun-

tries. It has been found in gravel beds near London. In the Royal Cabinet at Berlin there is a mass of 18 lbs. weight, supposed to be the largest ever found. Jussieu asserts, that the delicate insects in amber, which prove the tranquillity of its formation, are not European. M. Hauy has pointed out the following distinctions between mellite and copal, the bodies which most closely resemble amber. Mellite is infusible by heat. A bit of copal heated at the end of a knife takes fire, melting into drops, which flatten as they fall; whereas amber burns with spitting and frothing; and when its liquefied particles drop, they rebound from the plane which receives them. The origin of amber is at present involved in perfect obscurity, though the rapid progress of vegetable chemistry promises soon to throw light on it. Various frauds are practised with this substance. Neumann states as the common practices of workmen the two following: The one consists in surrounding the amber with sand in an iron pot, and cementing it with a gradual fire for forty hours, some small pieces placed near the sides of the vessel being occasionally taken out for judging of the effect of the operation: the second method, which he says is that most generally practised, is by digesting and boiling the amber about twenty hours with rapeseed oil, by which it is rendered both clear and hard.

* Werner has divided it into two subspecies, the white and the yellow; but there is little advantage in the distinction. Its ultimate constituents are the same with those of vegetable bodies in general; viz. carbon, hydrogen, and oxygen; but the proportions have not been ascertained.

In the second volume of the Edinburgh Philosophical Journal, Dr. Brewster has given an account of some optical properties of amber, from which he considers it established beyond a doubt that amber is an *indurated vegetable juice;* and that the traces of a regular structure, indicated by its action upon polarized light, are not the effect of the ordinary laws of crystallization by which *mellite* has been formed, but are produced by the same causes which influence the mechanical condition of gum arabic, and other gums, which are known to be formed by the successive deposition and induration of vegetable fluids.*

Amber is also used in varnishes. See VARNISH, and OIL of AMBER.

AMBERGRIS is found in the sea, near the coasts of various tropical countries; and has also been taken out of the intestines of the physeter macrocephalus, the spermaceti whale. As it has not been found in any whales but such as are dead or sick, its production is generally supposed to be owing to disease, though some have a little too peremptorily affirmed it to be the cause of the morbid affection. As no large piece has ever been found without a greater or less quantity of the beaks of the sepia octopodia, the common food of the spermaceti whale, interspersed throughout its substance, there can be little doubt of its originating in the intestines of the whale; for if it were occasionally swallowed by it only, and then caused disease, it must much more frequently be found without these, when it is met with floating in the sea, or thrown upon the shore.

Ambergris is found of various sizes, generally in small fragments, but sometimes so large as to weigh near two hundred pounds. When taken from the whale, it is not so hard as it becomes afterward on exposure to the air. Its specific gravity ranges from 780 to 926. If good, it adheres like wax to the edge of a knife with which it is scraped, retains the impression of the teeth or nails, and emits a fat odoriferous liquid on being penetrated with a hot needle. It is generally brittle; but, on rubbing it with the nail, it becomes smooth like hard soap. Its colour is either white, black, ash coloured, yellow, or blackish; or it is variegated, namely, gray with black specks, or gray with yellow specks. Its smell is peculiar, and not easy to be counterfeited. At 144° it melts, and at 212° is volatilized in the form of a white vapour. But, on a red-hot coal, it burns, and is entirely dissipated. Water has no action on it; acids, except nitric, act feebly on it; alkalis combine with it, and form a soap; ether and the volatile oils dissolve it; so do the fixed oils, and also ammonia, when assisted by heat; alcohol dissolves a portion of it, and is of great use in analyzing it, by separating its constituent parts. According to Bouillon la Grange, who has given the latest analysis of it, 3820 parts of ambergris consist of adipocere 2016 parts, a resinous substance 1167, benzoic acid 425, and coal 212. * But Bucholz could find no benzoic acid in it. Dr. Ure examined two different specimens with considerable attention. The one yielded benzoic acid, the other, equally genuine to all appearance, afforded none. See ADIPOCERE and INTESTINAL CONCRETION.

An alcoholic solution of ambergris, added in minute quantity to lavender water, tooth powder, hair powder, wash balls, &c. communicates its peculiar fragrance. Its retail price being in London so high as a guinea per oz. leads to many adulterations. These consist of various mixtures of benzoin, labdanum, meal, &c. scented with musk. The greasy appearance and smell which heated ambergris exhibits, afford good *criteria*, joined to its solubility in hot ether and alcohol.*

It has occasionally been employed in

medicine, but its use is now confined to the perfumer. Dr. Swediaur took thirty grains of it without perceiving any sensible effect. A sailor, who took half an ounce of it, found it a good purgative.

* **Amblygonite.** A greenish coloured mineral of different pale shades, marked on the surface with reddish and yellowish brown spots. It occurs massive and crystallized in oblique four-sided prisms. Lustre vitreous; cleavage parallel with the sides of an oblique four-sided prism of 106° 10′ and 77° 50′; fracture uneven; fragments rhomboidal; translucent; hardness, as feldspar; brittle; sp. gr. 3.0. Intumesces with the blow-pipe, and fuses with a reddish-yellow phosphorescence into a white enamel. It occurs in granite, along with green topaz and tourmaline, near Pinig in Saxony. It seems to be a species of spodumene.*

Amethyst. The amethyst is a gem of a violet colour, and great brilliancy, said to be as hard as the ruby or sapphire, from which it only differs in colour. This is called the oriental amethyst, and is very rare. When it inclines to the purple or rosy colour, it is more esteemed than when it is nearer to the blue. These amethysts have the same figure, hardness, specific gravity, and other qualities, as the best sapphires or rubies, and come from the same places, particularly from Persia, Arabia, Armenia, and the West Indies. The occidental amethysts are merely coloured crystals or quartz. See Quartz and Sapphire.

Amianthus, Mountain Flax. See Asbestus.

* **Ammonia,** called also Volatile Alkali. We shall first consider this substance in its purely scientific relations, and then detail its manufacture on the great scale, and its uses in the arts. There is a saline body, formerly brought from Egypt, where it was separated from soot by sublimation, but which is now made abundantly in Europe, called sal ammoniac. From this salt, pure ammonia can be readily obtained by the following process: Mix unslacked quicklime with its own weight of sal ammoniac, each in fine powder, and introduce them into a glass retort. Join to the beak of the retort, by a collar of caoutchouc, (a neck of an Indian rubber bottle answers well,) a glass tube about 18 inches long, containing pieces of ignited muriate of lime. This tube should lie in a horizontal position, and its free end, previously bent obliquely by the blow-pipe, should dip into dry mercury in a pneumatic trough. A slip of porous paper, as an additional precaution, may be tied round the tube, and kept moist with ether. If a gentle heat from a charcoal chauffer or lamp be now applied to the bottom of the retort, a gaseous body will bubble up through the mercury. Fill a little glass tube, sealed at one end, with the gas, and transfer it, closely stopped at the other end, into a basin containing water. If the water rise instantly and fill the whole tube, the gas is pure, and may be received for examination.

Ammonia is a transparent, colourless, and consequently invisible gas, possessed of elasticity, and the other mechanical properties of the atmospherical air. Its specific gravity is an important *datum* in chemical researches, and has been rather differently stated. Now, as no aeriform body is more easily obtained in a pure state than ammonia, this diversity among accurate experimentalists, shows the nicety of this statical operation. MM. Biot and Arago make it = 0.59669 by experiment, and by calculation from its elementary gases, they make it = 0.59438. Kirwan says, that 100 cubic inches weigh 18.16 gr. at 30 inches of bar. and 61° F., which compared to air reckoned 30.519, gives 0.59540. Sir H. Davy determines its density to be = 0.590, with which estimate the theoretic calculations of Dr. Prout, in the 6th volume of the Annals of Philosophy, agree.

This gas has an exceedingly pungent smell, well known by the old name of spirits of hartshorn. An animal plunged into it speedily dies. It extinguishes combustion, but being itself to a certain degree combustible, the flame of a taper immersed in it, is enlarged before going out. It has a very acrid taste. Water condenses it very rapidly. The following valuable table of its aqueous combinations has been given by Sir H. Davy.

Sp. Gr.	*Ammonia.*	*Water.*
0.8750	32.50	67.50
0.8875	29.25	70.75
0.9000	26.00	74.00
0.9054	25.37	74.63
0.9166	22.07	77.93
0.9255	19.54	80.46
0.9326	17.52	82.48
0.9385	15.88	84.12
0.9435	14.53	85.47
0.9476	13.46	86.54
0.9513	12.40	87.60
0.9545	11.56	88.44
0.9573	10.82	89.18
0.9597	10.17	89.83
0.9619	9.60	90.40
0.9692	9.50	90.50

Water is capable of dissolving easily about one-third of its weight of ammoniacal gas, or 460 times its bulk. Hence, when placed in contact with a tube filled with this gas, water rushes into it with explosive velocity. Probably the quantity of ammonia stated in the above table is too high by about one per cent.

Dr. Thomson states, in his System, vol. 2d. page 29. "Water, by my trials, is capable of absorbing 780 times its bulk of this gas; while, in the mean time, the bulk of the liquid increases from 6 to 10. The specific gravity of this solution is 0.900, which just accords with the increase of bulk." Correcting the first error where 6 is substituted for 9, a less excusable error comes to be examined. Taking the Doctor's own number for the specific gravity of the gas, it is evident that 780 times the volume, combined with water, would give nearly 36 by weight of gas in 100 of the liquid. But in the very same page he says, "It follows, from the experiments of Davy, that a *saturated* solution of ammonia is composed of 74.63 water and 25.37 ammonia." Hence, if that be correct, a liquid containing 36 per cent of ammonia is a manifest impossibility. In the very same page he gives Mr. Dalton's table, "which exhibits the quantity of ammonia contained in ammoniacal solutions of different specific gravities." In this table, opposite to the specific gravity 0.90 of the liquid ammonia, such as he made in his own trials, we have 22.2, a far different quantity from the number 36 equivalent to his 780 volumes. Sir H. Davy's table differs very little from that of Mr. Dalton, the truth probably lying between them. It is certain, indeed, that 100 parts of ammoniacal water, sp. gr. 0.900, instead of containing 36 parts, or 780 volumes, do not contain above 24 parts, or 520 volumes. Had Dr. Thomsom consulted Sir H. Davy's Elements of Chemical Philosophy, he would have found the following statement, p. 268. "At the temperature of 50°, under a pressure equal to 29.8 inches, water, I find, absorbs about 670 times its volume of gas, and becomes of specific gravity 0.875." In the table of Sir H. Davy, opposite 0.875, we have 32.5 per cent of ammonia. If any person will take the trouble of calculating, he will find that 670 inches of a gas, of which 100 cubic inches weigh 18 grs. in combining with one cubic inch of water weighing 252.5 grains, form a solution that must contain just 32.3 per cent of the condensed gas.

We thus perceive, that liquid ammonia, as the aqueous compound is termed, may like spirits be very accurately valued by its specific gravity. But it differs remarkably from alcoholic mixtures in this respect, that the strongest ammoniacal liquor, when it is diluted with water, suffers no condensation of volume. The specific gravity of the dilute, is the mean of that of its components. Hence, having one point accurately, we can compute all below it, by paying attention to the rule given under Specific Gravity. To procure aqueous ammonia, we may use either a common still and refrigeratory or a Woulfe's apparatus. The latter should be preferred. Into a retort we put a mixture of two parts of slaked lime, and one part of pulverized sal ammoniac, and having connected the beak of the retort with the Woulfe's apparatus, containing pure water, we then disengage the ammonia, by the application of heat. When gas ceases to be evolved, the addition of a little hot water will renew its disengagement, and ensure complete decomposition of the salt. Since sal ammoniac contains nearly $\frac{1}{3}$ its weight of ammonia, ten pounds of it should yield by economical treatment, 30 pounds of liquid, whose specific gravity is 0.950, which is as strong as the ordinary purposes of chemistry and medicine require; and it will form twice that quantity, or 60 pounds of the common water of ammonia, sold by apothecaries, which has rarely a smaller density than 0.978 or 0.980. There is no temptation to make it with the ammoniacal carbonate; but if this salt be accidentally present, it is instantly detected by its causing a milkiness in lime water.

Ammoniacal gas, perfectly dry, when mixed with oxygen, explodes with the electric spark, and is converted into water and nitrogen, as has been shown in an ingenious paper by Dr. Henry. But the simplest, and perhaps most accurate mode of resolving ammonia into its elementary constituents, is that first practised by M. Berthollet, the celebrated discoverer of its composition. This consists in making the pure gas traverse very slowly an ignited porcelain tube of a small diameter. The process, as lately repeated by M. Gay-Lussac, yielded from 100 cubic inches of ammonia, 200 cubic inches of constituent gases; of which by subsequent analysis, 50 were found to be nitrogen, and 150 hydrogen. Hence we see, that the reciprocal affinity of the ammoniacal elements had effected a condensation equal to one-half of the volume of the free gases. It appears, by the most recent determinations, that the specific gravity of hydrogen is 0.0694, compared to air as unity, and that of nitrogen, 0.9722. Three volumes of the former will therefore weigh 0.2082, and one of the latter, 0.9722; the sum of which numbers, 1.1804, divided by 2, ought to coincide with the experimental density of ammonia. Now, it is 0.5902, being an exact correspondence. And the ratio of the two weights, reduced to 100 parts, will be 82.36 nitrogen to 17.64 hydrogen. To reduce ammonia to the system of equivalents, or to find its saturating ratio on that scale where oxygen represents unity, we have this proportion 0.9722 : 1.75 : : 1.1804 : 2.1225, so that 2.125 may be called its prime equivalent:

We shall find this number deduced from analysis, confirmed by the synthesis of all the ammoniacal salts.

Dr. Prout, in an able memoir on the relation between the specific gravities of gaseous bodies, and the weights of their atoms, published in the 6th vol. of the Annals of Philosophy, makes the theoretical weight of the atom of ammonia to be only 1.9375 considering it as a compound of 1 atom of azote, and 1½ atoms of hydrogen. This statement appears to be a logical inference from Mr. Dalton's hypothesis of atomical combination. For water, the great groundwork of his atomic structure, is represented as a compound of one atom oxygen with one atom of hydrogen; and this atomical unit of hydrogen consists of two volumes of the gas. Hence three volumes of the gas must represent an atom and an half. But an atom is, by its very definition, indivisible. Dr. Prout in the 38th number of the Annals, restores the true proportions of 3 atoms hydrogen, + 1 azote. Our doctrine of equivalent primes, resting on the basis of experimental induction, claims no knowledge of the atomical constitution of bodies.

The alkaline nature of ammonia is demonstrated, not only by its neutralizing acidity, and changing the vegetable reds to purple or green, but also by its being attracted to the negative pole of a voltaic arrangement. When a pretty strong electric power is applied to ammonia in its liquid or solid combinations, simple decomposition is effected; but in contact with mercury, very mysterious phenomena occur. If a globule of mercury be surrounded with a little water of ammonia, or placed in a little cavity in a piece of sal ammoniac, and then subjected to the voltaic power by two wires, the negative touching the mercury, and the positive the ammoniacal compound, the globule is instantly covered with a circulating film, a white smoke rises from it, and its volume enlarges, whilst it shoots out ramifications of a semi-solid consistence over the salt. The amalgam has the consistence of soft butter, and may be cut with a knife. Whenever the electrization is suspended, the crab-like fibres retract towards the central mass, which soon, by the constant formation of white saline films, resumes its pristine globular shape and size. The enlargement of volume seems to amount occasionally to ten times that of the mercury, when a small globule is employed. Sir H. Davy, Berzelius, and MM. Gay-Lussac and Thenard, have studied this singular phenomenon with great care. They produced the very same substance by putting an amalgam of mercury and potassium into the moistened cupel of sal ammoniac. It becomes five or six times larger, assumes the consistence of butter, whilst it retains its metallic lustre.

What takes place in these experiments? In the second case, the substance of metallic aspect which we obtain is an ammoniacal hydruret of mercury and potassium. There is formed, besides, muriate of potash. Consequently a portion of the potassium of the amalgam, decomposes the water, becomes potash, which itself decomposes the muriate of ammonia. Thence result hydrogen and ammonia, which, in the nascent state, unite to the undecomposed amalgam. In the first experiment, the substance, which, as in the second, presents the metallic aspect, is only an ammoniacal hydruret of mercury; its formation is accompanied by the perceptible evolution of a certain quantity of chlorine at the positive pole. It is obvious, therefore, that the salt is decomposed by the electricity. The hydrogen of the muriatic acid, and the ammonia, both combine with the mercury. These hydrurets possess the following properties.

Their sp. gravity is in general below 3.0; exposed for some time to the temperature of 32° F. they assume considerable hardness, and crystallize in cubes, which are often as beautiful and large as those of bismuth. Ether and alcohol instantly destroy these amalgams, exciting a brisk effervescence with them, and reproducing the pure mercurial globule. These amalgams are slightly permanent in the air, if undisturbed; but the least agitation is fatal to their existence. MM. Gay-Lussac and Thenard found, by immersion in water, that mercury, in passing to the state of a hydruret, absorbed 3½ times its volume of hydrogen. The ammoniacal hydruret of mercury and potassium may exist by itself; but as soon as we attempt to separate or oxidize the potassium, its other constituent principles also separate. Hence this hydruret is speedily decomposed by the air, by oxygen gas, and in general by all bodies that act upon potassium. It is even affected by mercury, so that in treating it with this metal, we may easily determine the relative quantity of ammonia and hydrogen which it contains. We need only for this purpose take up the interior parts of the hydruret with a little iron spoon, fill up with it a little glass tube, already nearly full of mercury; and closing this with a very dry stopper, invert it in mercury equally dry. The hydruret will rise to the upper part of the tube, will be decomposed, especially by a slight agitation, and will give out hydrogen and ammonia in the ratio of 1 to 2.5.

The mere ammoniacal hydrurets contain but a very small quantity of hydrogen and ammonia. By supposing that in the ammoniacal hydruret of mercury, the hydrogen is to the ammonia in the same proportion as in the ammoniacal hydruret of mercury and potassium, it will appear that the first is formed in volume, of 1 of mercury, 3.47 hydrogen, and 8.67 ammoniacal gas, at the mean pressure and temperature of 30. and 60°; or in weight, of about 1800 parts of mercury, with 1 part of hydrogen, and 1 of ammonia.

Ammonia is not affected by a cherry-red heat. According to Guyton de Morveau, it becomes a liquid at about 40°—0°, or at 0°, the freezing point of mercury; but it is uncertain whether the appearances he observed may not have been owing to hygrometric water, as happens with chlorine gas. The ammoniacal liquid loses its pungent smell as its temperature sinks, till at —50°, it gelatinizes, if suddenly cooled; but if slowly cooled, it crystallizes.

Oxygen, by means of electricity, or a mere red heat, resolves ammonia into water and nitrogen. When there is a considerable excess of oxygen, it acidifies a portion of the nitrogen into nitrous acid, whence many fallacies in analysis have arisen. Chlorine and ammonia exercise so powerful an action on each other, that when mixed suddenly, a sheet of white flame pervades them. The simplest way of making this fine experiment, is to invert a mattrass, with a wide mouth and conical neck, over another with a taper neck, containing a mixture of sal ammoniac and lime, heated by a lamp. As soon as the upper vessel seems to be full of ammonia, by the overflow of the pungent gas, it is to be cautiously lifted up, and inserted, in a perpendicular direction, into a wide-mouthed glass decanter or flask, filled with chlorine. On seizing the two vessels thus joined, with the two hands covered with gloves, and suddenly inverting them, like a sandglass, the heavy chlorine and light ammonia, rushing in opposite directions, unite, with the evolution of flame. As one volume of ammonia contains, in a condensed state, one and a half of hydrogen, which requires for its saturation just one and a half of chlorine, this quantity should resolve the mixture into muriatic acid and nitrogen, and thereby give a ready analysis of the alkaline gas. If the proportion of chlorine be less, sal ammoniac and nitrogen are the results. The same thing happens on mixing the aqueous solutions of ammonia and chlorine. But if large bubbles of chlorine be let up into ammoniacal water of moderate strength, luminous streaks are seen in the dark to pervade the liquid, and the same reciprocal change of the ingredients is effected.

MM. Gay-Lussac and Thenard state that when 3 parts of ammoniacal gas, and 1 of chlorine, are mixed together, they condense into sal ammoniac; and azote, equal to 1-10th the whole volume, is given out. This result is at variance with their own theory of volumes.

Three of ammoniacal gas consist of 4½ hydrogen, and 1½ nitrogen in a condensed state; 1 of chlorine seizes 1 of hydrogen, to form 2 of muriatic acid gas, which precipitate with 2 of ammonia, in a pulverulent muriate. But the third volume of ammonia had parted with 1 volume of its hydrogen to the chlorine, and another half-volume of hydrogen, will unite with 0.166 of a volume of nitrogen, to form $\frac{0.66}{2} = 0.33$ of redundant ammonia, while 0.33 of a volume of nitrogen is left unemployed. Hence $\frac{2}{3}$ of a volume, or $\frac{1}{6}$ of the original bulk of the mixed gases, ought to remain; consisting of equal parts of ammonia and nitrogen, instead of 1-10th of azote, as the French chemists state.

Iodine has an analogous action on ammonia; seizing a portion of its hydrogen to form hydriodic acid, whence hydriodate of ammonia results; while another portion of iodine unites with the liberated nitrogen, to form the explosive pulverulent iodide.

Cyanogen and ammoniacal gas begin to act upon each other whenever they come into contact, but some hours are requisite to render the effect complete. They unite in the proportion nearly of 1 to 1½, forming a compound which gives a dark orange-brown colour to water, but dissolves in only a very small quantity in water. The solution does not produce prussian blue with the salts of iron.

By transmitting ammoniacal gas through charcoal ignited in a tube, prussic or hydrocyanic acid is formed.

The action of the alkaline metals on gaseous ammonia is very curious. When potassium is fused in that gas, a very fusible olive green substance, consisting of potassium, nitrogen, and ammonia, is formed; and a volume of hydrogen remains, exactly equal to what would result from the action on water, of the quantity of potassium employed. Hence, according to M. Thenard, the ammonia is divided into two portions. One is decomposed, so that its nitrogen combines with the potassium, and its hydrogen remains free, whilst the other is absorbed in whole or in part by the nitroguret of potassium. Sodium acts in the same manner. The olive substance is opaque, and it is only when in plates of extreme thinness that it appears semi-transparent; and it has nothing of the metallic appearance; it is heavier than water; and on minute inspection seems imperfectly crystallized.

When it is exposed to a heat progressively increased, it melts, disengages ammonia, and hydrogen and nitrogen, in the proportions constituting ammonia; then it becomes solid, still preserving its green colour, and is converted into a nitroguret of potassium or sodium. Exposed to the air at the ordinary temperature, it attracts only its humidity, but not its oxygen, and is slowly transformed into ammoniacal gas, and potash or soda. It burns vividly when projected into a hot crucible, or when heated in a vessel containing oxygen. Water and acids produce also sudden decomposition, with the extrication of heat. Alkalis or alkaline salts are produced. Alcohol likewise decomposes it with similar results. The preceding description of the compound of ammonia with potassium, as prepared by MM. Gay-Lussac and Thenard, was controverted by Sir H. Davy.

The experiments of this accurate chemist led to the conclusion, that the presence of moisture had modified their results. In proportion as more precautions are taken to keep every thing absolutely dry, so in proportion, is less ammonia regenerated. He seldom obtained as much as $\frac{1}{10}$ of the quantity absorbed; and he never could procure hydrogen and nitrogen in the proportions constituting ammonia; there was always an excess of nitrogen. The following experiment was conducted with the utmost nicety. $3\frac{1}{2}$ gr. of potassium were heated in 12 cubic inches of ammoniacal gas; 7.5 were absorbed, and 3.2 of hydrogen evolved. On distilling the olive-coloured solid in a tube of platina, 9 cubical inches of gas were given off, and half a cubical inch remained in the tube and adopters. Of the 9 cubical inches, one-fifth of a cubical inch only was ammonia; 10 measures of the permanent gas mixed with 7.5 of oxygen, and acted upon by the electrical spark, left a residuum of 7.5. He infers that the results of the analysis of ammonia, by electricity and potassium, are the same.

On the whole, we may legitimately infer that there is something yet unexplained in these phenomena. The potassium separates from ammonia, as much hydrogen, as an equal weight of it would from water. If two volumes of hydrogen be thus detached from the alkaline gas, the remaining volume, with the volume of nitrogen, will be left to combine with the potassium, forming a triple compound, somewhat analagous to the cyanides, a compound capable of condensing ammonia. For an account of a singular combination of ammonia, by which its volatility seems destroyed, see CHLORINE.

When ammoniacal gas is transmitted over ignited wires of iron, copper, platina, &c. it is decomposed completely, and though the metals are not increased in weight they have become extremely brittle. Iron, at the same témperature decomposes the ammonia, with double the rapidity that platinum does. At a high temperature, the protoxide of nitrogen decomposes ammonia.

Of the ordinary metals, zinc is the only one which liquid ammonia oxidizes and then dissolves. But it acts on many of the metallic oxides. At a high temperature the gas deoxidizes all those which are reducible by hydrogen. The oxides soluble in liquid ammonia, are the oxide of zinc, the protoxide and peroxide of copper, the oxide of silver, the third and fouth oxides of antimony, the oxide of tellurium, the protoxides of nickel, cobalt, and iron, the peroxides of tin, mercury, gold, and platinum. The first five are very soluble, the rest less so. These combinations can be obtained by evaporation, in the dry state, only with copper, antimony, mercury, gold, platinum, and silver; the four last of which, are very remarkable for their detonating property. See the particular metals.

All the acids are susceptible of combining with ammonia, and they almost all form with it neutral compounds. M. Gay-Lussac made the important discovery, that whenever the acid is gaseous, its combination with ammoniacal gas, takes place in a simple ratio of determinate volumes, whether a neutral or a subsalt be formed.

AMMONIACAL SALTS have the following general characters.—

1*st*, When treated with a caustic fixed alkali or earth, they exhale the peculiar smell of ammonia.

2*d*, They are generally soluble in water, and crystallizable.

3*d*, They are all decomposed at a moderate red heat; and if the acid be fixed, as the phosphoric or boracic, the ammonia comes away pure.

4*th*, When they are dropped into a solution of muriate of platina, a yellow precipitate falls.

1. *Acetate*. This saline compound was formerly called the spirit of Mindererus, who introduced it into medicine as a febrifuge sudorific. By saturating a pretty strong acetic acid with subcarbonate of ammonia, enclosing the liquid under the receiver of an air-pump, along with a saucerful of sulphuric acid, and exhausting the air, the salt will concrete in acicular crystals, which are nearly neutral. It may also be made very conveniently, by mixing hot saturated solutions of acetate of lead, and sulphate of ammonia, taking 100 of the first salt in its ordinary state, to 34.4 of the second, well dried at a heat

of 212°. Or even muriate of ammonia will answer in the proportion of 27.9 to 100 of the acetate. Acetate of ammonia has a cooling sweetish taste. It is deliquescent, and volatile at all temperatures; but it sublimes in the solid state at 250°. It consists of $75\frac{1}{3}$ of dry acetic acid, and $24\frac{2}{3}$ ammonia. When intended for medicine, it should always be prepared from pure acetic acid, and subcarbonate of ammonia.

Arseniate of ammonia may be formed by saturating the arsenic acid with ammonia, and evaporating the liquid. Crystals of a rhomboidal prismatic form are obtained. A binarseniate may also be made by using an excess of acid. At a red heat, the ammonia of both salts is decomposed, and the acid is reduced to the metallic state. Under the respective acids, an account of several ammoniacal salts will be found. As the muriate, however, constitutes an extensive manufacture, we shall enter here into some additional details concerning its production.

Sal ammoniac was originally fabricated in Egypt. The dung of camels and other animals constitutes the chief fuel used in that country. The soot is carefully collected. Globular glass vessels, about a foot in diameter, are filled within a few inches of their mouth with it, and are then arranged in an oblong furnace, where they are exposed to a heat gradually increased. The upper part of the glass balloon stands out of the furnace, and is kept relatively cool by the air. On the 3d day the operation is completed, at which time they plunge an iron rod occasionally into the mouths of the globes, to prevent them from closing up, and thus endanger the bursting of the glass.

The fire is allowed to go out; and on breaking the cooled globes, their upper part is found to be lined with sal ammoniac in hemispherical lumps, about 2½ inches thick, of a grayish white colour, semitransparent, and possessed of a degree of elasticity. 26 pounds of soot yield 6 of sal ammoniac. The ordinary mode of manufacturing sal ammoniac in Europe, is by combining with muriatic acid the ammonia resulting from the igneous decomposition of animal matters in close vessels. Cylinders of cast iron, fitted up as we have described under Acetic Acid, are charged with bones, horns, parings of hides, and other animal matters; and being exposed to a full red heat, an immense quantity of an impure liquid carbonate of ammonia distils over. Mr. Minish contrived a cheap method of converting this liquid into sal ammoniac. He digested it with pulveized gypsum, or simply made it percolate through a stratum of bruised gypsum; whence resulted a liquid sulphate of ammonia, and an insoluble carbonate of lime. The liquid, evaporated to dryness, was mixed with muriate of soda, put into large glass balloons, and decomposed by a subliming heat. Sal ammoniac was found above in its characteristic cake, while sulphate of soda remained below.

M. Leblanc of St. Denis, near Paris, invented another method of much ingenuity, which is described by a commission of eminent French chemists in the 19th volume of the Annales de Chimie, and in the Journal de Physique for the year 1794. He used tight brick kilns, instead of iron cylinders, for holding the materials to be decomposed. Into one he put a mixture of common salt and oil of vitriol; into another, animal matters. Heat extricated from the first, muriatic acid gas, and from the second, ammonia; which bodies being conducted by their respective flues into a third chamber lined with lead, and containing a stratum of water on its bottom, entered into combination, and precipitated in solid sal ammoniac on the roof and sides, or liquid at the bottom.

In the 20th volume of the Annales, a plan for employing bittern or muriate of magnesia to furnish the acid ingredient is described. An ingenious process on the same principles, was some time ago commenced at Borrowstounness in Scotland, by Mr. Astley. He imbued in a stove-room, heated by brick flues, parings of skins, horns, and other animal matters, with the muriate of magnesia, or mother water of the sea-salt works. The matters thus impregnated and dried, were subjected in a close kiln to a red heat, when the sal ammoniac vapour sublimed, and was condensed either in a solid form, into an adjoining chamber or chimney, or else into a stratum of water on its bottom. Muriate of magnesia at a red heat, evolves muriatic acid gas; an evolution probably aided in the present case, by the affinity of ammonia.

From coal soot likewise a considerable quantity of ammonia, in the state of carbonate and sulphate, may be obtained, either by sublimation or lixiviation with water. These ammoniacal products can afterwards be readily converted into the muriate, as above described. M. Leblanc used a kettle or eolipile for projecting steam into the leaden chamber to promote the combination. It is evident, that the exact neutralization, essential to sal ammoniac, might not be hit at first in these operations; but it could be afterwards effected by the separate addition of a portion of alkaline or acid gas. As the mother waters of the Cheshire salt-works contain only 3½ per cent. of muriate of magnesia, they are not suitable, like those of sea-salt works, for the above manufacture.*

* **Ammoniac (Gum).** This is a gum-resin, which consists, according to Braconnot, of 70 resin, 18.4 gum, 4.4 glutinous matter, 6 water, and 1.2 loss in 100 parts. It forms a milky solution with water; is partially soluble in alcohol; entirely in ether, nitric acid, and alkalis. Sp. gr. 1.200. It has a rather heavy smell, and a bitter sweet taste. It is in small agglutinated pieces of a yellowish white colour. It is used in medicine as an expectorant and antispasmodic.*

Ammonites. These petrifactions, which have likewise been distinguished by the name of *cornua ammonis*, and are called *snake-stones* by the vulgar, consist chiefly of lime-stone. They are found of all sizes, from the breadth of half an inch to more than two feet in diameter; some of them rounded, others greatly compressed, and lodged in different strata of stones and clays. They appear to owe their origin to shells of the nautilus kind.

Amomum. See **Pimento.**

* **Amphibole.** See **Hornblende** and **Actynolite.***

* **Amphigene.** See **Vesuvian.***

* **Amygdaloid.** A compound mineral, consisting of spheroidal particles or vesicles of lithomarge, green earth, calc spar, steatite, imbedded in a basis of fine grained green-stone, or wacke, containing sometimes also crystals of hornblende.*

Anacardium, Cashew Nut, or Marking Nut. At one extremity of the fruit of the cashew tree is a flattish kidney-shaped nut, between the rind of which and the thin outer shell is a small quantity of a red, thickish, inflammable, and very caustic liquor. This liquor forms a useful marking ink, as any thing written on linen or cotton with it, is of a brown colour, which gradually grows blacker, and is very durable.

* **Analcime.** Cubic Zeolite. This mineral is generally found in aggregated or cubic crystals, whose solid angles are replaced by three planes. External lustre between vitreous and pearly; fracture, flat conchoidal; colours, white, gray, or reddish; translucent. From its becoming *feebly* electrical by heat it has got the name analcime. Its sp. gr. is less than 2.6. It consists of 58 silica, 18 alumina, 2 lime, 10 soda, 8½ water, and 3½ loss in 100 parts. It is found in granite, gneiss, trap rocks and lavas, at Calton Hill Edinburgh, at Talisker in Skye, in Dumbartonshire, in the Hartz, Bohemia, and at the Ferroe Islands. The variety found at Somma has been called sarcolite, from its flesh colour.*

Analysis. Chemical analysis consists of a great variety of operations, performed for the purpose of separating the component parts of bodies. In these operations the most extensive knowledge of such properties of bodies as are already discovered must be applied, in order to produce simplicity of effect, and certainty in the results. Chemical analysis can hardly be executed with success by one who is not in possession of a considerable number of simple substances in a state of great purity, many of which, from their effects, are called reagents. The word analysis is applied by chemists to denote that series of operations, by which the component parts of bodies are determined, whether they be merely separated, or exhibited apart from each other; or whether these distinctive properties be exhibited by causing them to enter into new combinations, without the perceptible intervention of a separate state. The forming of new combinations is called synthesis; and, in the chemical examination of bodies, analysis or separation can scarcely ever be effected, without synthesis taking place at the same time.

As most of the improvements in the science of chemistry consist in bringing the art of analysis nearer to perfection, it is not easy to give any other rule to the learner than the general one of consulting and remarking the processes of the best chemists, such as Scheele, Bergmann, Berthollet, Kirwan, Vauquelin, and Berzelius. The bodies which present themselves more frequently for examination than others, are minerals and mineral waters. In the examination of the former, it was the habit of the earlier chemists to avail themselves of the action of fire, with very few humid processes, which are such as might be performed in the usual temperature of the atmosphere. Modern chemists have improved the process by fire, by a very extensive use of the blowpipe (see **Blow-pipe**); and have succeeded in determining the component parts of minerals to great accuracy in the humid way. For the method of analyzing mineral waters, see **Waters (Mineral)**; and for the analysis of metallic ores, see **Ores.**

Several authors have written on the examination of earths and stones.

The first step in the examination of consistent earths or stones is somewhat different from that of such as are pulverulent. Their specific gravity should first be examined; also their hardness, whether they will strike fire with steel, or can be scratched by the nail, or only by crystal, or stones of still greater hardness; also their texture, perviousness to light, and whether they be manifestly homogeneous or compound species, &c.

2d, In some cases, we should try whether they imbibe water, or whether water can extract any thing from them by ebullition or digestion.

3d, Whether they be soluble in, or effervesce with, acids, before or after pulverization; or whether decomposable by boiling in a strong solution of potash, &c. as gypsums and ponderous spars are.

4th, Whether they detonate with nitre.

5th, Whether they yield the fluor acid by distillation with sulphuric acid, or ammonia by distilling them with potash.

6th, Whether they be fusible *per se* with a blow-pipe, and how they are affected by soda, borax, and microcosmic salt; and whether they decrepitate when gradually heated.

7th, Stones that melt *per se* with the blow-pipe are certainly compound, and contain at least three species of earth, of which the calcareous is probably one; and if they give fire with steel, the siliceous is probably another.

The general process prescribed by the celebrated Vauquelin, in the 30th volume of the Annales de Chimie, is the clearest which has yet been offered to the chemical student.

If the mineral be very hard, it is to be ignited in a covered crucible of platinum, and then plunged into cold water, to render it brittle and easily pulverizable. The weight should be noted before and after this operation, in order to see if any volatile matter has been emitted. For the purpose of reducing stones to an impalpable powder, little mortars of highly hardened steel are now made, consisting of a cylindrical case and pestle. A mortar of agate is also used for subsequent levigation, About ten grains of the mineral should be treated at once; and after the whole 100 grains have been reduced in succession to an impalpable powder, they should be weighed, to find what increase may have been derived from the substance of the agate. This addition may be regarded as silica.

Of the ten primary earths, only four are usually met with in minerals, viz. silica, alumina, magnesia, and lime, associated with some metallic oxides, which are commonly iron, manganese, nickel, copper and chromium.

If neither acid nor alkali be expected to be present, the mineral is mixed in a silver crucible, with thrice its weight of pure potash and a little water. Heat is gradually applied to the covered crucible, and is finally raised to redness; at which temperature it ought to be maintained for an hour. If the mass, on inspection, be a perfect glass, silica may be regarded as the chief constituent of the stone; but if the vitrification be very imperfect and the bulk much increased, alumina may be supposed to predominate. A brownish or dull green colour indicates the presence of iron; a bright grass-green, which is imparted to water, that of manganese; and from a greenish-yellow, chromium may be expected. The crucible, still a little hot, being first wiped, is put into a capsule of porcelain or platinum; when, warm distilled water is poured upon the alkaline earthy mass, to detach it from the crucible. Having transferred the whole of it into the capsule, muriatic acid is poured on, and a gentle heat applied, if necessary, to accomplish its solution. If the liquid be of an orange-red colour, we infer the presence of iron; if of a golden-yellow, that of chromium; and if of a purplish-red, that of manganese. The solution is next to be evaporated to dryness, on a sand-bath, or over a lamp, taking care so to regulate the heat, that no particles be thrown out. Towards the end of the evaporation, it assumes a gelatinous consistence. At this period it must be stirred frequently with a platinum spatula or glass rod, to promote the disengagement of the muriatic acid gas. After this, the heat may be raised to fully 212° F. for a few minutes. Hot water is to be now poured on in considerable abundance, which dissolves every thing except the silica. By filtration, this earth is separated from the liquid; and being edulcorated with hot water, it is then dried, ignited, and weighed. It constitutes a fine white powder, insoluble in acids, and feeling gritty between the teeth. If it be coloured, a little dilute muriatic acid must be digested on it, to remove the adhering metallic, particles, which must be added to the first solution. This must now be reduced by evaporation to the bulk of half a pint. Carbonate of potash being then added, till it indicates alkaline excess, the liquid must be made to boil for a little. A copious precipitation of the earth and oxides is thus produced. The whole is thrown on a filter, and after it is so drained as to assume a semi-solid consistence, it is removed by a platinum blade, and boiled in a capsule for some time, with solution of pure potash. Alumina and glucina are thus dissolved, while the other earths and the metallic oxides remain.

This alkalino-earthy solution, separated from the rest, by filtration, is to be treated with an excess of muriatic acid; after which carbonate of ammonia being added also in excess, the alumina is thrown down while the glucina continues dissolved. The first earth separated by filtration, washed, dried, and ignited, gives the quantity of alumina. The nature of this may be further demonstrated, by treating it with dilute sulphuric acid, and sulphate of potash, both in equivalent quantities, when the whole will be converted into alum. (See Alum). The filtered liquid will deposite its glucina, on dissipating the ammonia, by ebullition. It is to be separated by filtration, to be washed, ignited, and weighed.

The matter undissolved by the digestion of the liquid potash, may consist of lime, magnesia, and metallic oxides. Dilute sulphuric acid must be digested on it for some time. The solution is to be evaporated to dryness, and heated to expel the excess of acid. The saline solid matter being now diffused in a moderate quantity of water, the sulphate of magnesia will be dissolved, and along with the metallic sulphates, may be separated from the sulphate of lime by the filter. The latter being washed with a little water, dried, ignited, and weighed, gives, by the scale of equivalents, the quantity of lime in the mineral. The magnesian and metallic solution being diluted with a large quantity of water, is to be treated with bicarbonate of potash, which will precipitate the nickel, iron, and chromium, but retain the magnesia and manganese, by the excess of carbonic acid. Hydrosulphuret of potash will throw down the manganese, from the magnesian solution. The addition of pure potash, aided by gentle ebullition, will then precipitate the magnesia. The oxide of manganese may be freed from the sulphuretted hydrogen, by ustulation.

The mingled metallic oxides must be digested with abundance of nitric acid, to acidify the chromium. The liquid is next treated with potash, which forms a soluble chromate, while it throws down the iron and nickel. The chromic acid may be separated from the potash by muriatic acid, and digestion with heat, washed, dried till it becomes a green oxide, and weighed. The nickel is separated from the iron, by treating their solution in muriatic acid, with water of ammonia. The latter oxide which falls, may be separated by the filter, dried and weighed. By evaporating the liquid, and exposing the dry residue to a moderate heat, the ammoniacal salt will sublime and leave the oxide of nickel behind. The whole separate weights must now be collected in one amount, and if they constitute a sum within two per cent. of the primitive weight, the analysis may be regarded as giving a satisfactory account of the composition of the mineral. But if the deficiency be considerable, then some volatile ingredient, or some alkali or alkaline salt, may be suspected.

A portion of the mineral broken into small fragments, is to be ignited in a porcelain retort, to which a refrigerated receiver is fitted. The water or other volatile and condensable matter, if any be present, will thus be obtained. But if no loss of weight be sustained by ignition, alkali, or a volatile acid, may be looked for. The latter is usually the fluoric. It may be expelled by digestion with sulphuric acid. It is exactly characterized by its property of corroding glass.*

Beside this general method, some others may be used in particular cases.

Thus, to discover a small portion of alumina or magnesia in a solution of a large quantity of lime, pure ammonia may be applied, which will precipitate the alumina or magnesia (if any be), but not the lime. Distilled vinegar applied to the precipitate will discover whether it be alumina or magnesia.

2dly, A minute portion of lime or barytes, in a solution of alumina or magnesia, may be discovered by the sulphuric acid, which precipitates the lime and barytes: the solution should be dilute, else the alumina also would be precipitated. If there be not an excess of acid, the oxalic acid is still a nicer test of lime: 100 grains of gypsum contain about 33 of lime: 100 grains of sulphate of barytes contain 66 of barytes; 100 grains of oxalate of lime contain 43.8 of lime. The insolubility of sulphate of barytes in 500 times its weight of boiling water, sufficiently distinguishes it. From these data the quantities are easily investigated.

3dly, A minute proportion of alumina in a large quantity of magnesia may be discovered, either by precipitating the whole, and treating it with distilled vinegar; or by heating the solution nearly to ebullition, and adding more carbonate of magnesia, until the solution is perfectly neutral, which it never is when alumina is contained in it, as this requires an excess of acid to keep it in solution. By these means the alumina is precipitated in the state of embryon alum, which contains about half its weight of alumina (or, for greater exactness, it may be decomposed by boiling it in volatile alkali). After the precipitation, the solution should be largely diluted, as the sulphate of magnesia, which remained in solution while hot, would precipitate when cold, and mix with the embryon alum.

4thly, A minute portion of magnesia in a large quantity of alumina is best separated by precipitating the whole, and treating the precipitate with distilled vinegar.

Lastly, Lime and barytes are separated by precipitating both with the sulphuric acid, and evaporating the solution to a small compass, pouring off the liquor, and treating the dried precipitate with 500 times its weight of boiling water; what remains undissolved is sulphate of barytes.

The inconveniences of employing much heat, are obvious, and Mr. Lowitz informs us, that they may be avoided without the least disadvantage. Over the flame of a spirit lamp, that will hold an ounce and half, and is placed in a cylindrical tin furnace four inches high and three in diameter, with air-holes, and a cover perforated to hold the crucible, he boils the stone prepared as directed above, stirring it frequently. His crucible, which, as well as the spatula, is of very fine silver, holds two ounces and a half, or three ounces. As soon as the matter is boiled dry, he pours in as much hot water as he used at first; and this he repeats two or three times more, if the refractoriness of the fossil require it. Large tough bubbles arising during the boiling, are in general a sign that the process will be attended with success. Even the sapphire, though the most refractory of all Mr. Lowitz tried, was not more so in this than in the dry way.

Sir H. Davy observes, that the boracic acid is very useful in analyzing stones that contain a fixed alkali; as its attraction for the different earths at the heat of ignition is considerable, and the compounds it forms with them are easily decomposed by the mineral acids dissolved in water. His process is as follows: Let 100 grains of the stone to be examined be reduced to a fine powder, mixed with 200 grains of boracic acid, and fused for about half an hour at a strong red heat in a crucible of platina or silver. Digest the fused mass in an ounce and half of nitric acid diluted with seven or eight times the quantity of water, till the whole is decomposed; and then evaporate the solution till it is reduced to an ounce and half, or two ounces. If the stone contained silex, it will separate in this process, and must be collected on a filter, and edulcorated with distilled water, to separate the saline matter. The fluid, mixed with all the water that has been passed through the filter, being evaporated till reduced to about half a pint, is to be saturated with carbonate of ammonia, and boiled with an excess of this salt, till all that will precipitate has fallen down. The earths and metallic oxides being separated by filtration, mix nitric acid with the clear fluid till it has a strongly sour taste, and then evaporate till the boracic acid remains free. Filter the fluid, evaporate it to dryness, and expose it to a heat of 450° F. when the nitrate of ammonia will be decomposed, and the nitrate of potash or soda will remain in the vessel. The earths and metallic oxides, that remained on the filter, may be distinguished by the common processes. The alumina may be separated by solution of potash, the lime by sulphuric acid, the oxide of iron by succinate of ammonia, the manganese by hydrosulphuret of potash, and the magnesia by pure soda.

* Lately carbonate or nitrate of barytes has been introduced into mineral analysis with great advantage, for the fluxing of stones, that may contain alkaline matter. See the English Translation of M. Thenard's volume on analysis.*

Under the head of mineral analysis, nothing is of so much general importance as the examination of soils, with a view to the improvement of such as are less productive, by supplying the ingredients they want in due proportions to increase their fertility. To Lord Dundonald and Mr. Kirwan we are much indebted for their labours in this field of inquiry; but Sir H. Davy, assisted by the labours of these gentlemen, the facts and observations of Mr. Young, and his own skill in chemistry, having given at large, in a manner best adapted for the use of the practical farmer, an account of the methods to be pursued for this purpose, we shall here copy them.

The substances found in soils are certain mixtures or combinations of some of the primitive earths, animal and vegetable matter in a decomposing state, certain saline compounds, and the oxide of iron. These bodies always retain water, and exist in very different proportions in different lands, and the end of analytical experiments is the detection of their quantities and mode of union.

The earths commonly found in soils are principally silex, or the earth of flints; alumina, or the pure matter of clay; lime, or calcareous earth; and magnesia: for the characters of which see the articles. Silex composes a considerable part of hard gravelly soils, hard sandy soils, and hard stony lands. Alumina abounds most in clayey soils, and clayey loams; but even in the smallest particles of these soils, it is generally united with silex and oxide of iron. Lime always exists in soils in a state of combination, and chiefly with carbonic acid, when it is called carbonate of lime. This carbonate in its hardest state is marble; in its softest, chalk. Lime united with sulphuric acid is sulphate of lime, or gypsum; with phosphoric acid, phosphate of lime, or the earth of bones. Carbonate of lime, mixed with other substances, composes chalky soils and marls, and is found in soft sandy soils. Magnesia is rarely found in soils: when it is, it is combined with carbonic acid, or with silex and alumina. Animal decomposing matter exists in different states, contains much carbonaceous substance, volatile alkali, inflammable aëriform products, and carbonic acid. It is found chiefly in lands lately manured. Vegetable decomposing matter usually contains still more carbonaceous substance, and differs from the preceding principally in not producing volatile alkali. It forms a great proportion of all peats, abounds in rich mould, and is found in larger or smaller quantities in all lands. The saline compounds are few, and in small quantity: they are chiefly muriate of soda, or common salt, sulphate of magnesia, muriate and sulphate of potash, nitrate of lime, and the mild alkalis. Oxide of iron, which is the same with the rust produced by exposing iron to air and water, is found in all soils, but most abundantly in red and yellow clays, and red and yellow siliceous sands.

The instruments requisite for the analysis of soils are few. A pair of scales capable of holding a quarter of a pound of common soil, and turning with a single grain when loaded: a set of weights, from a quarter of a pound troy to a grain: a wire sieve, coarse enough to let peppercorn pass through: an Argand lamp and stand: a few glass bottles, Hessian crucibles, and china or queen's ware evaporating basins: a Wedgwood pestle and mortar: some filters made of half a sheet of blotting paper, folded so as to contain a pint of liquid, and greased at the edges: a bone knife: and an apparatus for collecting and measuring aëriform fluids.

The reagents necessary are muriatic acid, sulphuric acid, pure volatile alkali dissolved in water, solution of prussiate of potash, soap lye, and solutions of carbonate of ammonia, muriate of ammonia, neutral carbonate of potash, and nitrate of ammonia.

1. When the general nature of the soil of a field is to be ascertained, specimens of it should be taken from different places, two or three inches below the surface, and examined as to the similarity of their properties. It sometimes happens, that on plains the whole of the upper stratum of the land is of the same kind, and in this case one analysis will be sufficient. But in valleys, and near the beds of rivers, there are very great differences, and it now and then occurs, that one part of a field is calcareous, and another part siliceous; and in this and analogous cases, the portions different from each other should be analyzed separately. Soils when collected, if they cannot be examined immediately, should be preserved in phials quite filled with them, and closed with ground glass stopples. The most convenient quantity for a perfect analysis is from two hundred grains to four hundred. It should be collected in dry weather, and exposed to the air till it feels dry. Its specific gravity may be ascertained, by introducing into a phial, which will contain a known quantity of water, equal bulks of water and of the soil; which may easily be done, by pouring in water till the phial is half full, and then adding the soil till the fluid rises to the mouth. The difference between the weight of the water, and that of the soil, will give the result. Then if the bottle will contain four hundred grains of water, and gains two hundred grains when half filled with water and half with soil, the specific gravity of the soil will be 2; that is, it will be twice as heavy as water: and if it gained one hundred and sixty-five grains, its specific gravity would be 1825, water being 1000. It is of importance that the specific gravity of a soil should be known, as it affords an indication of the quantity of animal and vegetable matter it contains; these substances being always most abundant in the lighter soils. The other physical properties of soils should likewise be examined before the analysis is made, as they denote, to a certain extent, their composition, and serve as guides in directing the experiments. Thus siliceous soils are generally rough to the touch, and scratch glass when rubbed upon it: aluminous soils adhere strongly to the tongue, and emit a strong earthy smell when breathed upon: and calcareous soils are soft, and much less adhesive than aluminous soils.

2. Soils, when as dry as they can be made by exposure to the air, still retain a considerable quantity of water, which adheres with great obstinacy to them, and cannot be driven off without considerable heat: and the first process of analysis is to free them from as much of this water as possible, without affecting their composition in other respects. This may be done by heating the soil for ten or twelve minutes in a china basin over an Argand lamp, at a temperature equal to 300° F.; and if a thermometer be not used, the proper degree of heat may easily be ascertained by keeping a piece of wood in the basin in contact with its bottom; for as long as the colour of the wood remains unaltered, the heat is not too high; but as soon as it begins to be charred, the process must be stopped. In several experiments, in which Sir H. Davy collected the water that came over at this degree of heat, he found it pure, without any sensible quantity of other volatile matter being produced. The loss of weight in this process must be carefully noted; and if it amount to 50 grains in 400 of the soil, this may be considered as in the greatest degree absorbent and retentive of water, and will generally be found to contain a large proportion of aluminous earth: if the loss be not more than 10 or 20 grains, the land may be considered as slightly absorbent and retentive, and the siliceous earth as most abundant.

3. None of the loose stones, gravel, or

large vegetable fibres, should be separated from the soil, till the water is thus expelled; for these bodies are often highly absorbent and retentive, and consequently influence the fertility of the land. But after the soil has been heated as above; these should be separated by the sieve, after the soil has been gently bruised in a mortar. The weights of the vegetable fibres or wood, and of the gravel and stones, should be separately noted down, and the nature of the latter ascertained: if they be calcareous, they will effervesce with acids; if siliceous, they will scratch glass; if aluminous, they will be soft, easily scratched with a knife, and incapable of effervescing with acids.

4. Most soils, beside stones and gravel, contain larger or smaller proportions of sand of different degrees of fineness; and the next operation necessary is to separate this sand from the parts more minutely divided, such as clay, loam, marl, and vegetable and animal matter. This may be done sufficiently by mixing the soil well with water; as the coarse sand will generally fall to the bottom in the space of a minute, and the finer in two or three; so that by pouring the water off after one, two, or three minutes, the sand will be for the most part separated from the other substances; which, with the water containing them, must be poured into a filter. After the water has passed through, what remains on the filter must be dried and weighed; as must also the sand; and their respective quantities must be noted down. The water must be preserved, as it will contain the saline matter, and the soluble animal or vegetable matter, if any existed in the soil.

5. A minute analysis of the sand thus separated is seldom or never necessary, and its nature may be detected in the same way as that of the stones and gravel. It is always siliceous sand, or calcareous sand, or both together. If it consist wholly of carbonate of lime, it will dissolve rapidly in muriatic acid with effervescence; but if it consists partly of this and partly of siliceous matter, a residuum will be left after the acid has ceased to act on it, the acid being added till the mixture has a sour taste, and has ceased to effervesce. This residuum is the siliceous part; which being washed, dried, and heated strongly in a crucible, the difference of its weight from that of the whole, will indicate the quantity of the calcareous sand.

6. The finely divided matter of the soil is usually very compound in its nature; it sometimes contains all the four primitive earths of soils, as well as animal and vegetable matter; and to ascertain the proportions of these with tolerable accuracy, is the most difficult part of the subject. The first process to be performed in this part of the analysis is the exposure of the fine matter of the soil to the action of muriatic acid. This acid, diluted with double its bulk of water, should be poured upon the earthy matter in an evaporating basin, in a quantity equal to twice the weight of the earthy matter. The mixture should be often stirred, and suffered to remain for an hour, or an hour and half, before it is examined. If any carbonate of lime, or of magnesia, exist in the soil, they will have been dissolved in this time by the acid, which sometimes takes up likewise a little oxide of iron, but very seldom any alumina. The fluid should be passed through a filter; the solid matter collected, washed with distilled or rain water, dried at a moderate heat, and weighed. Its loss will denote the quantity of solid matter taken up. The washings must be added to the solution; which, if not sour to the taste, must be made so by the addition of fresh acid; and a little solution of prussiate of potash must be mixed with the liquor. If a blue precipitate occur, it denotes the presence of oxide of iron, and the solution of the prussiate must be dropped in, till no further effect is produced. To ascertain its quantity, it must be collected on a filter in the same manner as the other solid precipitates, and heated red: the result will be oxide of iron. Into the fluid freed from oxide of iron a solution of carbonate of potash must be poured till all effervescence ceases in it, and till its taste and smell indicate a considerable excess of alkaline salt. The precipitate that falls down is carbonate of lime; which must be collected on a filter, dried at a heat below that of redness, and afterward weighed. The remaining fluid must be boiled for a quarter of an hour, when the magnesia, if there be any, will be precipitated combined with carbonic acid, and its quantity must be ascertained in the same manner as that of the carbonate of lime. If any minute proportion of alumina should, from peculiar circumstances, be dissolved by the acid, it will be found in the precipitate with the carbonate of lime, and it may be separated from it by boiling for a few minutes with soap lye sufficient to cover the solid matter: for this lye dissolves alumina, without acting upon carbonate of lime. Should the finely divided soil be sufficiently calcareous to effervesce very strongly with acids, a simple method of ascertaining the quantity of carbonate of lime, sufficiently accurate in all common cases, may be adopted. As carbonate of lime in all its states contains a determinate quantity of acid, which is about 45 parts in a hundred by weight,

the quantity of this acid given out during the effervescence occasioned by its solution in a stronger acid, will indicate the quantity of carbonate of lime present. Thus, if you weigh separately one part of the matter of the soil, and two parts of the acid diluted with an equal quantity of water, and mix the acid slowly in small portions with the soil, till it ceases to occasion any effervescence, by weighing the mixture, and the acid that remains, you will find the quantity of carbonic acid lost; and for every four grains and half so lost you will estimate ten grains of carbonate of lime. You may also collect the carbonic acid in the *pneumatic apparatus for the analysis of soils*, described in the article LABORATORY; and allow for every ounce measure of the carbonic acid, two grains of carbonate of lime.

7. The quantity of insoluble animal and vegetable matter may next be ascertained with sufficient precision, by heating it to a strong red heat in a crucible over a common fire, till no blackness remains in the mass, stirring it frequently meanwhile with a metallic wire. The loss of weight will ascertain the quantity of animal and vegetable matter there was, but not the proportions of each. If the smell emitted, during this process, resemble that of burnt feathers, it is a certain indication of the presence of some animal matter; and a copious blue flame almost always denotes a considerable proportion of vegetable matter. Nitrate of ammonia, in the proportion of twenty grains to a hundred of the residuum of the soil, will greatly accelerate this process, if the operator be in haste; and not affect the result, as it will be decomposed and evaporate.

8. What remains after this decomposition of the vegetable and animal matter, consists generally of minute particles of earthy matter, which are usually a mixture of alumina and silex with oxide of iron. To separate these, boil them two or three hours in sulphuric acid diluted with four times its weight of water, allowing a hundred and twenty grains of acid for every hundred grains of the residuum. If any thing remain undissolved by this acid, it may be considered as silex, and be separated, washed, dried, and weighed, in the usual manner. Carbonate of ammonia being added to the solution in quantity more than sufficient to saturate the acid, the alumina will be precipitated; and the oxide of iron, if any, may be separated from the remaining liquid by boiling it. It scarcely ever happens, that any magnesia or lime escapes solution in the muriatic acid; but if it should, it will be found in the sulphuric acid; from which it may be separated as directed above for the muriatic. This method of analysis is sufficiently precise for all common purposes: but if very great accuracy be an object, the residuum after the incineration must be treated with potash, and in the manner in which stones are analyzed, as given in the first part of this article.

9. If the soil contained any salts, or soluble vegetable or animal matter, they will be found in the water used for separating the sand. This water must be evaporated to dryness at a heat below boiling. If the solid matter left be of a brown colour, and inflammable, it may be considered as partly vegetable extract. If its smell, when exposed to heat, be strong and fetid, it contains animal mucilaginous, or gelatinous matter. If it be white and transparent, it may be considered as principally saline. Nitrate of potash or of lime is indicated in this saline matter by its sparkling when thrown on burning coals: sulphate of magnesia may be detected by its bitter taste: and sulphate of potash produces no alteration in a solution of carbonate of ammonia, but precipitates a solution of muriate of barytes.

10. If sulphate or phosphate of lime be suspected in the soil, a particular process is requisite to detect it. A given weight of the entire soil, as four hundred grains for instance, must be mixed with one third as much powdered charcoal, and kept at a red heat in a crucible for half an hour. The mixture must then be boiled a quarter of an hour in half a pint of water, and the solution, being filtered, exposed some days to the open air. If any soluble quantity of sulphate of lime, or gypsum, existed in the soil, a white precipitate will gradually form in the fluid, and the weight of it will indicate the proportion.

Phosphate of lime, if any be present, may be separated from the soil after the process for gypsum. Muriatic acid must be digested upon the soil in quantity more than sufficient to saturate the soluble earths. The solution must be evaporated, and water poured upon the solid matter. This fluid will dissolve the compounds of earths with the muriatic acid, and leave the phosphate of lime untouched.

11. When the examination of a soil is completed, the products should be classed, and their quantities added together; and if they nearly equal the original quantity of soil, the analysis may be considered as accurate. It must however be observed, that when phosphate or sulphate of lime is discovered by the independent process, No. 10, just mentioned, a correction must be made for the general process, by subtracting a sum equal to their weight from the quantity of carbonate of lime obtain-

ed by precipitation from the muriatic acid. In arranging the products, the form should be in the order of the experiments by which they are obtained. Thus 400 grains of a good siliceous sandy soil may be supposed to contain, grains.

Of water of absorption,		18
Of loose stones and gravel principally siliceous,		42
Of undecompounded vegetable fibres,		10
Of fine siliceous sand,		200
Of minutely divided matter, separated by filtration, and consisting of,		
Carbonate of lime,	25	
Carbonate of magnesia,	4	
Matter destructible by heat, principally vegetable,	10	
Silex,	40	
Alumina,	32	
Oxide of iron,	4	
Soluble matter, principally sulphate of potash and vegetable extract,	5	
Gypsum,	3	
Phosphate of lime,	2	
		125
Amount of all the products,		395
Loss,		5
		400

In this instance the loss is supposed small; but in general, in actual experiments, it will be found much greater, in consequence of the difficulty of collecting the whole quantities of the different precipitates; and when it is within thirty for four hundred grains, there is no reason to suspect any want of due precision in the processes.

12. When the experimenter is become acquainted with the use of the different instruments, the properties of the reagents, and the relations between the external and chemical qualities of soils, he will seldom find it necessary to perform, in any one case, all the processes that have been described. When his soil, for instance, contains no notable proportion of calcareous matter, the action of the muriatic acid, No. 6. may be omitted: in examining peat soils, he will principally have to attend to the operation by fire and air, No. 7.; and in the analysis of chalks and loams, he will often be able to omit the experiment with sulphuric acid, No. 8.

In the first trials that are made by persons unacquainted with chemistry, they must not expect much precision of result. Many difficulties will be met with; but in overcoming them the most useful kind of practical knowledge will be obtained; and nothing is so instructive in experimental science as the detection of mistakes. The correct analyst ought to be well grounded in general chemical information; but perhaps there is no better mode of gaining it than that of attempting original investigations. In pursuing his experiments, he will be continually obliged to learn from books the nature of the substances he is employing or acting upon; and his theoretical ideas will be more valuable in being connected with practical operations, and acquired for the purpose of discovery.

The analysis of vegetable substances requires various manipulations and peculiar attention, as their principles are extremely liable to be altered by the processes to which they are subjected. It was long before the analysis was brought to any degree of perfection.

Some of the immediate materials of vegetables are separated by the means of Nature in a state of greater or less purity, as the gums, resins, and balsams, that exude from plants. The compound juices contain various matters, that may be separated by the appropriate reagents. [illegible], [illegible], and [illegible] in water, take up certain principles in the first instance, and acids will extract others that water will not dissolve. The mode of separating and distinguishing these materials will easily be collected from their characters, as given under the head Vegetable Kingdom, and under the different articles themselves.

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* As the ultimate constituents of all vegetable substances are carbon, hydrogen, and oxygen, with occasionally azote, the products of their last decomposition afford a method of ascertaining the proportions of these elementary bodies. MM. Gay-Lussac and Thenard contrived a very elegant apparatus for vegetable and animal analysis, in which the matter in a dried state was mixed with chlorate of potash, and formed into minute pellets. These pellets being projected through the aperture of a stop-cock of peculiar construction into an ignited glass tube, were suddenly resolved into carbonic acid and water. The former product was received over mercury, and estimated by its condensation with potash; the other was [illegible] by [illegible] [illegible] of [illegible], and was measured by the increase of weight [illegible] a communication [illegible] [illegible] [illegible]. By previously taking the quantity of [illegible], which a given weight of the chlorate of potash yielded by ignition was known, and hence the carbon, hydrogen, and oxygen, deduced from the organic substance, as well as the relative [illegible] of the gaseous products.

M. Berzelius modified the above apparatus, and employed the organic [illegible] the quantity of this acid given out during the effervescence occasioned by its solution in a stronger acid, will indicate the quantity of carbonate of lime present. Thus, if you weigh separately one part of the matter of the soil, and two parts of the acid diluted with an equal quantity of water, and mix the acid slowly in small portions with the soil, till it ceases to occasion any effervescence, by weighing the mixture, and the acid that remains, you will find the quantity of carbonic acid lost; and for every four grains and half so lost you will estimate ten grains of carbonate of lime. You may also collect the carbonic acid in the *pneumatic apparatus for the analysis of soils*, described in the article LABORATORY; and allow for every ounce measure of the carbonic acid, two grains of carbonate of lime.

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Some of the immediate materials of vegetables are separated to our hands by Nature in a state of greater or less purity; as the gums, resins, and balsams, that exude from plants. The expressed juices contain various matters, that may be separated by the appropriate reagents. Maceration, infusion, and decoction in water, take up certain parts soluble in this menstruum; and alcohol will extract others that water will not dissolve. The mode of separating and distinguishing these materials will easily be collected from their characters, as given under the head VEGETABLE KINGDOM, and under the different articles themselves.

* As the ultimate constituents of all vegetable substances are carbon, hydrogen, and oxygen, with occasionally azote, the problem of their final analysis resolves into a method of ascertaining the proportion of these elementary bodies. MM. Gay-Lussac and Thenard contrived a very elegant apparatus for vegetable and animal analysis, in which the matter in a dried state was mixed with chlorate of potash, and formed into minute pellets. These pellets being projected through the intervention of a stop-cock of peculiar structure into an ignited glass tube, were instantly resolved into carbonic acid and water. The former product was received over mercury, and estimated by its condensation with potash; the latter was intercepted by ignited muriate of lime, and was measured by the increase of weight which it communicates to this substance. By previous trials, the quantity of oxygen which a given weight of the chlorate of potash yielded by ignition was known; and hence the carbon, hydrogen, and oxygen, derived from the organic substance, as well as the residual azote, of the gaseous products.

M. Berzelius modified the above apparatus, and employed the organic product in combination with a base, generally oxide of lead. He mixed a certain weight of this neutral compound with a known quantity of pure chlorate of potash, and triturated the whole with a large quantity of muriate of soda, for the purpose of moderating the subsequent combustion. This mingled dry powder is put into a glass tube about half an inch diameter, and eight or ten inches long, which is partially enclosed in a fold of tin-plate, hooped with iron wire. One end of the tube is hermetically sealed beforehand, the other is now drawn to a pretty fine point by the blowpipe. This termination is inserted into a glass globe about an inch diameter, which joins it to a long tube containing dry muriate of lime in its middle, and dipping at its other extremity into the mercury of a pneumatic trough. The first tube, with its protecting tin case, being exposed gradually to ignition, the enclosed materials are resolved into carbonic acid, water, and azote, which come over, and are estimated as above described. M. Gay-Lussac has more recently employed peroxide of copper to mix with the organic substance to be analyzed; because while it yields its oxygen to hydrogen and carbon, it is not acted on by azote; and thus the errors resulting from the formation of nitric acid with the chlorate of potash are avoided. Berzelius has afforded satisfactory evidence by his analyses, that the simple apparatus which he employed is adequate to every purpose of chemical research. Dr. Prout has described, in the Annals of Philosophy for March 1820, a very neat form of apparatus for completing analyses of organic substances with the heat of a lamp. Hydrogen having the power in minute quantities of modifying the constitution of the organic bodies, requires to be estimated with corresponding minuteness. Mr. Porrett has very ingeniously suggested, that its quantity may be more accurately determined by the proportion of oxide of copper that is revived, than by the product of water. Dilute sulphuric acid being digested on the residual cupreous powder, will instantly dissolve the oxide, and leave the reduced metal; whose weight will indicate, by the scale of equivalents, the hydrogen expended in its reduction. One of hydrogen corresponds to 9 of water, and 32 of copper.

Under the different vegetable and animal products, we shall take care to state their ultimate constituents by the most correct and recent analyses. The peculiar substances which water, alcohol, ether, and other solvents, can separate from an organic body may be called the immediate products of the vegetable or animal kingdom; while the carbon, hydrogen, oxygen, and azote, discoverable by igneous analysis, are the ultimate constituent elements. To the former class belong sugar, gum, starch, oils, resins, gelatin, urea, organic acids and alkalis, &c. which see.*

* **Anatase.** Octohedrite, oxide of titanium, rutile, and titane rutile. This mineral shows a variety of colours by reflected light, from indigo-blue to reddish-brown. By transmitted light, it appears greenish-yellow. It is found usually in small crystals, octohedrons, with isosceles triangular faces. Structure lamellar; it is semi-transparent, or opaque; fragments splendent, adamantine; scratches glass; brittle; sp. gr. 3.85. It is a pure oxide of titanium. It has been found only in Dauphiny and Norway; and is a very rare mineral. It occurs in granite, gneiss, mica slate, and transition limestone.*

* **Andalusite.** A massive mineral, of a flesh and sometimes rose-red colour. It is, however, occasionally crystallized in rectangular four-sided prisms, verging on rhomboids. The structure of the prisms is lamellar, with joints parallel to their sides. Translucent; scratches quartz; is easily broken; sp. gr. 3.165. Infusible by the blow-pipe; in which respect it differs from feldspar, though called felspath apyre by Haüy. It is composed of 52 alumina, 32 silica, 8 potash, 2 oxide of iron, and 6 loss, Vauq. It belongs to primitive countries, and was first found in Andalusia in Spain. It is found in mica slate in Aberdeenshire, and in the Isle of Unst; Dartmoor in Devonshire; in mica slate at Killiney, near Dublin, and at Douce Mountain, county Wicklow.*

* **Andreolite.** See **Harmotome.***

* **Anhydrite.** Anhydrous gypsum. There are six varieties of it.—

1. Compact, has various shades, of white, blue, and red; massive and kidney-shaped; dull aspect; splintery or conchoidal fracture; translucent on the edges; is scratched by fluor, but scratches calc spar; somewhat tough; specific gravity 2.850. It is dry sulphate of lime, with a trace of sea salt. It is found in the salt mines of Austria and Salzburg, and at the foot of the Harz mountains. 2. Granular, the scaly of Jameson. Is found in massive concretions, of which the structure is confusedly foliated. White or bluish colour, of a pearly lustre; composition as above, with one per cent. of sea salt. It occurs in the salt mines of Halle; sp. gr. 2.957. 3. Fibrous. Massive; glimmering, pearly lustre; fracture in delicate parallel fibres; scarcely translucent; easily broken. Found at Halle, Ischel, and near Brunswick. 4. Radiated. Blue, sometimes spotted with red; radiated, splendent fracture; partly splintery; translucent; not hard; sp. gr. 2.940. 5. Sparry, or cube spar. Milk-white colour, passing sometimes into grayish and reddish white; short four-sided prisms, having two of the opposite sides much broader than the other two; and occasionally the lateral edges are truncated, whence results an eight-sided prism; lustre, splendent, pearly. Foliated fracture. Threefold rectangular cleavage. Cubical fragments. Translucent. Scratches calc spar. Brittle. Sp. gr. 2.9. This is the muriacite of some writers. It is doubly refracting. It is said to contain one per cent. of sea salt. It is found at Bex in Switzerland, and Halle in the Tyrol. 6. Siliciferous, or vulpinite. Massive concretions of a laminated structure, translucent on the edges, splendent, and brittle. Grayish-white, veined with bluish-gray. Sp. gr. 2.88. It contains eight per cent. silex. The rest is sulphate of lime. It is called by statuaries, Marmo bardiglio di Bergamo, and takes a fine polish. It derives its name from Vulpino in Italy, where it accompanies lime.*

Anil, or Nil. This plant, from the leaves of which indigo is prepared, grows in America.

Animal Kingdom. The various bodies around us, which form the objects of chemical research, have all undergone a number of combinations and decompositions before we take them in hand for examination. These are all consequences of the same attractions or specific properties that we avail ourselves of; and are modified likewise by virtue of the situations and temperatures of the bodies presented to each other. In the great mass of unorganized matter, the combinations appear to be much more simple than such as take place in the vessels of organized beings, namely, plants and animals: in the former of which there is not any peculiar structure of tubes conveying various fluids; and in the latter there is not only an elaborate system of vessels, but likewise, for the most part, an augmentation of temperature. From such causes as these it is, that some of the substances afforded by animal bodies are never found either in vegetables or minerals; and so likewise in vegetables are found certain products never unequivocally met with among minerals. Hence, among the systematical arrangements used by chemists, the most general is that which divides bodies into three kingdoms, the animal, the vegetable, and the mineral.

Animal, as well as vegetable bodies, may be considered as peculiar apparatus for carrying on a determinate series of chemical operations. Vegetables seem capable of operating with fluids only, and at the temperature of the atmosphere, as we have just noticed. But most animals have a provision for mechanically dividing solids by mastication, which answers the same purpose as grinding, pounding, or levigation, does in our experiments; that is to say, it enlarges the quantity of surface to be acted upon by solvents. The process carried on in the stomach appears to be of the same kind as that which we distinguish by the name of digestion; and the bowels, whatever other uses they may serve, evidently form an apparatus for filtering or conveying off the fluids; while the more solid parts of the aliments, which are probably of such a nature as not to be rendered fluid, but by an alteration which would perhaps destroy the texture of the machine itself, are rejected as useless. When this filtered fluid passes into the circulatory vessels, through which it is driven with considerable velocity by the mechanical action of the heart, it is subjected, not only to all those changes which the chemical action of its parts is capable of producing, but is likewise exposed to the air of the atmosphere in the lungs, into which that elastic fluid is admitted by the act of respiration. Here it undergoes a change of the same nature as happens to other combustible bodies when they combine with its vital part, or oxygen. This vital part becomes condensed, and combines with the blood, at the same time that it gives out a large quantity of heat, in consequence of its own capacity for heat being diminished. A small portion of azote likewise is absorbed, and carbonic acid is given out. Some curious experiments of Spallanzani show, that the lungs are not the sole organs by which these changes are effected. Worms, insects, shells of land and sea animals, egg shells, fishes, dead animals, and parts of animals, even after they have become putrid, are capable of absorbing oxygen from the air, and giving out carbonic acid. They deprive atmospheric air of its oxygen as completely as phosphorus. Shells, however, lose this property when their organization is destroyed by age. Amphibia, deprived of their lungs, lived much longer in the open air, than others in air destitute of oxygen. It is remarkable, that a larva, weighing a few grains, would consume almost as much oxygen in a given time as one of the amphibia a thousand times its bulk. Fishes, alive and dead, animals, and parts of animals, confined under water in jars, absorbed the oxygen of the atmospheric air over the water. Muscles, tendons, bones, brain, fat, and blood, all absorbed oxygen in different proportions; but the blood did not absorb most, and bile appeared not to absorb any.

It would lead us too far from our purpose, if we were to attempt an explanation of the little we know respecting the manner in which the secretions or combinations that produce the various animal and vegetable substances are effected, or the uses of those substances in the economy of plants and animals. Most of them are very different from any of the products of the mineral kingdom. We shall therefore only add, that these organized beings are so contrived, that their existence continues, and all their functions are performed, as long as the vessels are supplied with food or materials to occupy the place of such as are carried off by evaporation from the surface, or otherwise; and as long as no great change is made, either by violence or disease, in those vessels, or the fluids they contain. But as soon as the entire process is interrupted in any very considerable degree, the chemical arrangements become altered; the temperature in land animals is changed; the minute vessels are acted upon and destroyed; life ceases, and the admirable structure, being no longer sufficiently perfect, loses its figure, and returns, by new combinations and decompositions, to the general mass of unorganized matter, with a rapidity which is usually greater, the more elaborate its construction.

† Within the sphere of vitality, peculiar laws of decomposition and recomposition seem to prevail, in like manner as within the sphere of the voltaic circuit. Indeed each gland seems to have a capacity to induce peculiar corpuscular reactions, giving rise to its appropriate secretions. In the living stomach, food passes to the state of chyme; when in the absence of life, the same matter, at the same temperature, would putrefy.†

The parts of vegetable or animal substances may be obtained, for chemical examination, either by simple pressure, which empties the vessels of their contents; by digestion in water, or in other fluids, which dissolve certain parts, and often change their nature; by destructive distillation, in which the application of a strong heat alters the combination of the parts, and causes the new products to pass over into the receiver in the order of their volatility; by spontaneous decomposition or fermentation, wherein the component parts take a new arrangement, and form compounds which did not for the most part exist in the organized substance; or, lastly, the judicious chemist will avail himself of all these several methods singly, or in combination. He will, according to circumstances, separate the parts of an animal or vegetable substance by pressure, assisted by heat; or by digestion or boiling in various fluids, added in the retort which contains the substance under examination. He will attend particularly to the products which pass over, whether they be permanently elastic, or subject to condensation in the temperatures we are able to produce. In some cases, he will suffer the spontaneous decomposition to precede the application of chemical methods; and in others, he will attentively mark the changes which the products of his operations undergo in the course of time, whether in closed vessels, or exposed to the open air. Thus it is, that, in surveying the ample field of nature, the philosophical chemist possesses numerous means of making discoveries, if applied with judgment and sagacity; though the progress of discovery, so far from bringing us nearer the end of our pursuit, appears continually to open new scenes; and, by enlarging our powers of investigation, never fails to point out additional objects of enquiry.

Animal and vegetable substances approach each other by insensible gradations; so that there is no simple product of the one which may not be found in greater or less quantity in the other. The most general distinctive character of animal substances is that of affording volatile alkali by destructive distillation. Some plants, however, afford it likewise. Neither contain it ready formed; but it appears to be produced by the combination of hydrogen and azote, during the changes produced either by fire, or the putrefactive process. See Ammonia.

Our knowledge of the products of the animal kingdom, by the help of chemical analysis, is not yet sufficiently matured to enable us to arrange them according to the nature of their component parts, which appear to consist chiefly of hydrogen, oxygen, carbon, and azote; and with these, sulphur, phosphorus, lime, magnesia, and soda, are frequently combined in variable proportions.

* The following are the peculiar chemical products of animal organization. Gelatin, albumen, fibrin, caseous matter, colouring matter of blood, mucus, urea, picromel, osmazome, sugar of milk, and sugar of diabetes. The compound animal products are the various solids and fluids, whether healthy or morbid, that are found in the animal body; such as muscle, skin, bone, blood, urine, bile, morbid concretions, brain, &c.*

When animal substances are left exposed to the air, or immersed in water or other fluids, they suffer a spontaneous change, which is more or less rapid according to circumstances. The spontaneous change of organized bodies is distinguished by the name of fermentation. In vegetable bodies there are distinct stages or periods of this process, which have been divided into the vinous, acetous, and putrefactive fermentations. Animal substances are susceptible only of the two latter, during which, as in all other spontaneous changes, the combinations of chemical principles become in general more and more simple. There is no doubt but much instruction might be obtained from accurate observations of the putrefactive processes in all their several varieties and situations; but the loathsomeness and danger attending on such enquiries have hitherto greatly retarded our progress in this department of chemical science. See Fermentation (Putrefactive).

Anime, improperly called gum animé, is a resinous substance imported from New Spain and the Brazils. There are two kinds, distinguished by the names of oriental and occidental. The former is dry, and of an uncertain colour, some specimens being greenish, some reddish, and some of the brown colour of myrrh. The latter is in yellowish, white, transparent, somewhat unctuous tears, and partly in larger masses, brittle, of a light pleasant taste, easily melting in the fire, and burning with an agreeable smell. Like resins, it is totally soluble in alcohol, and also in oil. Water takes up about 1-16th of the weight of this resin by decoction. The spirit, drawn off by distillation, has a considerable degree of the taste and flavour of the animé; the distilled water discovers on its surface some small portion of essential oil.

This resin is used by perfumers, and also in certain plasters, wherein it has been supposed to be of service in nervous affections of the head and other parts; but there are no reasons to think that, for medical purposes, it differs from common resins.

Anneal. We know too little of the arrangement of particles, to determine what it is that constitutes or produces brittleness in any substance. In a considerable number of instances of bodies which are capable of undergoing ignition, it is found that sudden cooling renders them hard and brittle. This is a real inconvenience in glass, and also in steel, when this metallic substance is required to be soft and flexible. The inconveniences are avoided by cooling them very gradually, and this process is called annealing. Glass vessels, or other articles, are carried into an oven or apartment near the great furnace, called the leer, where they are permitted to cool, in a greater or less time, according to their thickness and bulk. The annealing of steel, or other metallic bodies, consists simply in heating them, and suffering them to cool again either upon the hearth of the furnace, or in any other situation where the heat is moderate, or at least the temperature is not very cold.

† Malleability, ductility and toughness, in substances susceptible of the annealing process, are probably dependent on the quantity of caloric remaining in combination with their particles, while in the solid state. When malleable metals are hammered, they give out heat and become harder, more rigid and more dense, until a certain maximum is attained. Afterwards they neither heat nor harden, and crush to pieces, if the process be not suspended. Exposed to the fire until softened, on cooling they are found to have regained the properties of which percussion had deprived them; and they may be again hammered, heated, hardened, and condensed. The sudden abstraction of caloric from the exterior strata of particles in a piece of thick glass, is not attended by a corresponding abstraction of this principle from among the particles within, owing to the slowness, with which glass conducts heat. Hence cohesion is not general; and the particles are not arranged uniformly, unless the cooling be very slow, so as to allow the refrigeration, within and without, to be nearly simultaneous. As it never can be perfectly simultaneous in thick glass, it is never perfectly well annealed. The process would be more perfect, were the articles subjected to radiant heat only; as this, when projected from red-hot surfaces, penetrates through glass, as I have ascertained. By gradually making up fires of charcoal at about 4 inches distance on each side of a glass tube of about an inch and a quarter in thickness, and with a very small bore, I was enabled to heat and bend it. From its situation, it was only subjected to radiant heat.†

Annotto. The pellicles of the seeds of the *bixa orellana*, a liliaceous shrub, from 15 to 20 feet high in good ground, afford the red masses brought into Europe, under the name of Annotto, Orlean, and Roucou.

The annotto commonly met with among us is moderately hard, of a brown colour on the outside, and a dull red within. It is difficultly acted upon by water, and tinges the liquor only of a pale brownish yellow colour. In rectified spirit of wine it very readily dissolves, and communicates a high orange or yellowish-red. Hence it is used as an ingredient in varnishes, for giving more or less of an orange cast to the simple yellows. Alkaline salt renders it perfectly soluble in boiling water, without altering its colour.

Besides its use in dyeing, it is employed for colouring cheese.

* **Anthophyllite.** A massive mineral of a brownish colour; sometimes also crystallized, in thin flat six-sided prisms, streaked lengthwise. It has a false metallic lustre, glistening and pearly. In crystals, transparent. Massive, only translucent on the edges. It does not scratch glass, but fluate of lime. Specific gravity 3.2. Somewhat hard but exceedingly brittle. Infusible alone before the blow-pipe, but with borax it gives a grass-green transparent bead. It consists of 56 silica, 13.3 alumina, 14 magnesia, 3.33 lime, 6 oxide of iron, 3 oxide of manganese, 1.43 water, and 2.94 loss in 100. It is found Konigsberg in Norway.*

* **Anthracite.** Blind coal, Kilkenny coal, or glance-coal. There are three varieties. 1. Massive, the conchoidal of Jameson. Its colour is iron-black, sometimes tarnished on the surface, with a splendent metallic lustre. Fracture conchoidal, with a pseudo-metallic lustre. It is brittle and light. It yields no flame, and leaves whitish ashes. It is found in the newest floetz formations, at Meissner in Hesse, and Walsall in Staffordshire. 2. Slaty anthracite. Colour black, or brownish-black. Imperfect slaty in one direction, with a slight metallic lustre. Brittle. Specific gravity 1.4 to 1.8. Consumes without flame. It is composed of 72 carbon, 13 silica, 3.3 alumina, and 3.5 oxide of iron. It is found in both primitive and secondary rocks; at Calton Hill, Edinburgh; near Walsall Staffordshire; in the southern parts of Brecknockshire, Carmarthenshire, and Pembrokeshire, whence it is called Welsh culm; near Cumnock, and Kilmarnock, Ayrshire; and most abundantly at Kilkenny, Ireland. 3. Columnar anthracite. In small short prismatic concretions, of an iron-black colour with a tarnished metallic lustre. It is brittle, soft, and light. It yields no flame or smoke. It forms a thick bed near Sanquhar, in Dumfries-shire; at Saltcoats and New Cumnock, in Ayrshire. It occurs also at Meissner in Hesse.*

Antimony. The word antimony is always used in commerce to denote a metallic ore, consisting of sulphur combined with the metal, which is properly called antimony. Sometimes this sulphuret is termed crude antimony, to distinguish it from the pure metal, or regulus, as it was formerly called. According to Professor Proust, the sulphuret contains 26 per cent of sulphur. He heated 100 parts of antimony with an equal weight of sulphur in a glass retort, till the whole was well fused and the excess of sulphur expelled, and the sulphuret remaining was 135. The result was the same after repeated trials: 100 parts of antimony, with 300 of red sulphuret of mercury, afforded 135 to 136 of sulphuret. These artificial sulphurets lost nothing by being kept in fusion an hour; and heated with an equal weight of sulphur, they could not be made to take up more. Some of the native sulphurets of the shops, however, appear to have a small portion more of sulphur united with them, as they will take up an addition of 7 or 8 per cent of antimony.

Antimony is of a dusky white colour, very brittle, and of a plated or scaly texture. Its specific gravity, according to Brisson, is 6.7021, but Bergmann makes it 6.86. Soon after ignition it melts, and by a continuance of the heat it becomes oxidized, and rises in white fumes, which may afterwards be volatilized a second time, or fused into a hyacinthine glass, according to the management of the heat: the first were formerly called argentine flowers of regulus of antimony. In closed vessels the antimony rises totally without decomposition. This metallic substance is not subject to rust by exposure to air, though its surface becomes tarnished by that means Its oxides are a little soluble in water; and in this respect they resemble the oxide of arsenic, by an approach toward the acid state.

* There are certainly three, probably four, distinct combinations of antimony and oxygen: 1. The protoxide of Berzelius is a blackish-gray powder, obtained from a mixture of powder of antimony and water, at the positive pole of a voltaic circuit. Heat enables this oxide to absorb oxygen rapidly, converting it into the tritoxide. According to Berzelius, it consists of 100 of metal, and 4.65 oxygen. It must be confessed, however, that the *data* for fixing these proportions are very doubtful. 2. The deutoxide may be obtained by digesting the metal in powder in muriatic acid, and pouring the solution into water of potash. Wash and dry the precipitate. It is a powder of a dirty white colour, which melts at a moderate red heat, and crystallizes as it cools. According to Berzelius, it consists of 84.3 metal + 15.7 oxygen. 3. The tritoxide, or antimonious acid, is the immediate product of the combustion of the metal, called of old from its fine white colour, the argentine flowers of antimony. It may also be formed by digesting hot nitric acid on antimony. When fused with one-fourth of antimony, the whole becomes deutoxide. It forms the salts called antimonites with the different bases. According to Berzelius, the tritoxide consists of about 80 metal + 20 oxygen. 4. The peroxide, or antimonic acid, is formed, when the metal in powder is ignited along with six times its weight of nitre in a silver crucible. The excess of potash and nitre being afterwards separated by hot water, the anti-

moniate of potash is then to be decomposed by muriatic acid, when the insoluble antimonic acid of a straw colour will be obtained. Nitro-muriatic acid likewise converts the metal into the peroxide. Though insoluble in water, it reddens the vegetable blues. It does not combine with acids. At a red heat oxygen is disengaged, and antimonious acid results. Berzelius infers its composition to be 73.5 metal + 26.5 oxygen. It is difficult to reconcile the above three portions of oxygen to one prime equivalent for antimony. The number 11. gives the best approximation to Berzelius's analyses. We shall then have the

			In 100 parts,
Protoxide	11 metal	+ 1 oxy. or	$91.\frac{2}{3} + 8.\frac{1}{3}$
Deutoxide	11	+ 2	84.6 + 15.4
Tritoxide	11	+ 3	78.6 + 21.4
Peroxide	11	+ 4	73.4 + 26.6

The second and fourth numbers agree perfectly with experiment; the first oxide is too imperfectly known to enter into the argument; and the third number, though it indicates a little more oxygen than Berzelius assigns, gives less than Proust.

Chlorine gas and antimony combine with combustion, and a bichloride results. This was formerly prepared by distilling a mixture of two parts of corrosive sublimate with one of antimony. The substance which came over having a fatty consistence, was called butter of antimony. It is frequently crystallized in four-sided prisms. It is fusible and volatile at a moderate heat; and is resolved by water alone into the white oxide and muriatic acid. Being a bichloride, it is eminently corrosive, like the bichloride of mercury, from which it is formed. It consists of 45.7 chlorine + 54.3 antimony, according to Dr. John Davy's analysis, when the composition of the sulphuret is corrected by its recent exact analysis by Berzelius. But 11. antimony + 2 primes chlorine = 9.0, give the proportion per cent of 44.1 + 55.5; a good coincidence, if we consider the circuitous process by which Dr. Davy's analysis was performed. Three parts of corrosive sublimate, and one of metallic antimony, are the equivalent proportions for making butter of antimony. Iodine and antimony combine by the aid of heat into a solid iodide, of a dark-red colour. The phosphuret of this metal is obtained by fusing it with solid phosphoric acid. It is a white semi-crystalline substance. The sulphuret of antimony exists abundantly in nature. See ORES of ANTIMONY. It consists, according to Berzelius, of 100 antimony + 37.25 sulphur. The proportion given by the equivalent ratio is 100 + 36.5. Other analysts have found 30, 33, and 35 to 100 of metal. Berzelius admits that there may be a slight error in his numbers. The only important alloys of antimony are those of lead and tin; the former constitutes type metal, and contains about one-sixteenth of antimony; the latter alloy is employed for making the plates on which music is engraved.

The salts of antimony are of two different orders; in the first, the deutoxide acts the part of a salifiable base; in the second, the tritoxide and peroxide, act the part of acids, neutralizing the alkaline and other bases, to constitute the antimonites and antimoniates.

The only distinct combination of the first order entitled to our attention, is the triple salt called tartrate of potash and antimony, or tartar emetic, and which, by M. Gay-Lussac's new views, would be styled cream-tartrate of antimony. This constitutes a valuable and powerful medicine, and therefore the mode of preparing it should be correctly and clearly defined. As the dull white deutoxide of antimony is the true basis of this compound salt, and as that oxide readily passes by mismanagement into the tritoxide or antimonious acid, which is altogether unfit for the purpose, adequate pains should be taken to guard against so capital an error. In former editions of the British Pharmacopœias, the glass of antimony was prescribed as the basis of tartar emetic. More complex and precarious formulæ have been since introduced. The new edition of the Pharmacopée Française has given a recipe, which appears, with a slight change of proportions, to be unexceptionable. Take of the sulphuretted vitreous oxide of antimony levigated, and acidulous tartrate of potash, equal parts. Form a powder, which is to be put into an earthen or silver vessel, with a sufficient quantity of pure water. Boil the mixture for half an hour, adding boiling water from time to time; filter the hot liquor, and evaporate to dryness in a porcelain capsule; dissolve in boiling water the result of the evaporation, evaporate till the solution acquires the spec. grav. 1.161, and then let it repose, that crystals be obtained, which, by this process, will be pure. By another recipe, copied, with some alteration from Mr. Phillips's prescription, into the appendix of the French Pharmacopœia, a subsulphate of antimony is formed first of all, by digesting two parts of sulphuret of antimony in a moderate heat, with three parts of oil of vitriol. This insoluble subsulphate being well washed, is then digested in a quantity of boiling water, with its own weight of cream of tartar, and evaporated to the density 1.161, after which it is filtered hot. On cooling, crystals of the triple tartrate are obtained. One might imagine, that there is a chance of obtaining by this process, a mixture of sulphate of potash, and perhaps of a triple sulphate of antimony, along with the tartar emetic. Probably this does not happen, for it is said to yield crystals, very pure, very white, and without any mixture whatever.

Pure tartar emetic is in colourless and transparent tetrahedrons or octohedrons: It reddens litmus. Its taste is nauseous and caustic. Exposed to the air, it effloresces slowly. Boiling water dissolves half its weight, and cold water a fifteenth part. Sulphuric, nitric, and muriatic acids, when poured into a solution of this salt, precipitate its cream of tartar; and soda, potash, ammonia, or their carbonates, throw down its oxide of antimony. Barytes, strontites, and lime waters, occasion not only a precipitate of oxide of antimony, like the alkalis, but also insoluble tartrates of these earths. That produced by the alkaline hydrosulphurets, is wholly formed of kermes; while that caused by sulphuretted hydrogen, contains both kermes and cream of tartar. The decoctions of several varieties of cinchona, and of several bitter and astringent plants, equally decompose tartar emetic; and the precipitate then always consists of the oxide of antimony, combined with the vegetable matter and cream of tartar. Physicians ought therefore to beware of such incompatible mixtures. When tartar emetic is exposed to a red heat, it first blackens, like all organic compounds, and afterwards leaves a residuum of metallic antimony and subcarbonate of potash. From this phenomenon, and the deep brownish-red precipitate, by hydrosulphurets, this antimonial combination may readily be recognized. The precipitate may further be dried on a filter, and ignited with black flux, when a globule of metallic antimony will be obtained. Infusion of galls is an active precipitant of tartar emetic.

This salt, in an undue dose, is capable of acting as a poison. The best antidotes are demulcent drinks, infusions of bark, tea, and sulphuretted hydrogen water, which instantly converts the energetic salt into a relatively mild sulphuret: anodynes are useful afterwards. The powder of tartar emetic, mixed with hog's-lard, and applied to the skin of the human body, raises small vesications.

The composition of this salt, according to M. Thenard, is 35.4 acid, 39.6 oxide, 16.7 potash, and 8.2 water. The presence of the latter ingredient is obvious, from the undisputed phenomenon of efflorescence. If we adopt the new views of M. Gay-Lussac, this salt may be a compound of a prime equivalent of tartar = 23.825, with a prime equivalent of deutoxide of antimony = 13. On this hypothesis we would have the following proportions:

2 primes acid	=	16.75	45.4
1 prime potash	=	5.95	16.2
1 prime water	=	1.125	3.1
1 oxide of antimony	=	13.00	35.3
		36.825	100.0

But very little confidence can be reposed in such atomical representations.

The deutoxide seems to have the property of combining with sulphur in various proportions. To this species of compound must be referred the liver of antimony, glass of antimony, and *crocus metallorum* of the ancient apothecaries. Sulphuretted hydrogen forms, with the deutoxide of antimony, a compound which possessed at one time great celebrity in medicine, and of which a modification has lately been introduced into the art of calico printing. By dropping hydrosulphuret of potash, or of ammonia, into the cream-tartrate, or into mild muriate of antimony, the hydrosulphuret of the metallic oxide precipitates of a beautiful deep orange colour. This is *kermes mineral.* Cluzel's process for obtaining a fine *kermes*, light, velvety, and of a deep purple-brown, is the following: one part of pulverized sulphuret of antimony, 22½ parts of crystallized subcarbonate of soda, and 200 parts of water, are to be boiled together in an iron pot. Filter the hot liquor into warm earthen pans, and allow them to cool very slowly. At the end of 24 hours the kermes is deposited. Throw it on a filter, wash it with water which had been boiled and then cooled out of contact with air. Dry the kermes at a temperature of 85°, and preserve in corked phials. Whatever may be the process employed, by boiling the liquor after cooling and filtration, on new sulphuret of antimony, or upon that which was left in the former operation, this new liquid will deposite, on cooling, a new quantity of kermes. Besides the hydrosulphuretted oxide of antimony, there is formed a sulphuretted hydrosulphuret of potash or soda. Consequently, the alkali seizes a portion of the sulphur from the antimonial sulphuret, water is decomposed, and whilst a portion of its hydrogen unites to the alkaline sulphuret, its oxygen, and the other portion of its hydrogen, combine with the sulphuretted antimony. It seems, that the resulting kermes remains dissolved in the sulphuretted hydrosulphuret of potash or soda; but as it is less soluble in the cold than the hot, it is partially precipitated by refrigeration. If we pour into the supernatant liquid, after the kermes is deposited and removed, any acid, as the dilute nitric, sulphuric, or muriatic, we decompose the sulphuretted hydrosulphuret of potash or soda. The alkaline base being laid hold of, the sulphuretted hydrogen and sulphur to which they were united are set at liberty; the sulphur and kermes fall together, combine with it, and form an orange-coloured compound, called the golden sulphuret of antimony. It is a hydroguretted sulphuret of antimony. Hence, when it is digested with warm muriatic acid, a large residuum of sulphur is obtained, amounting sometimes to 12 per cent. Kermes is composed by Thenard, of 20.3 sulphuretted hydrogen, 4.15 sulphur, 72.76 oxide of antimony, 2.79 water and loss; and the golden sulphuret consists of 17.87 sulphuretted hydrogen, 68.3 oxide of antimony, and 12 sulphur.

By evaporating the supernatant kermes liquid, and cooling, crystals form, which have been lately employed by the calico printer, to give a topical orange. These crystals are dissolved in water, and the solution being thickened with paste or gum, is applied to cloth in the usual way. When the cloth is dried, it is passed through a dilute acid, when the orange precipitate is deposited and fixed on the vegetable fibres.

An empirical antimonial medicine, called James's powder, has been much used in this country. The inventor called it his *fever powder*, and was so successful in his practice with it, that it obtained very great reputation, which it still in some measure retains. Probably, the success of Dr. James was in great measure owing to his free use of the bark, which he always gave as largely as the stomach would bear, as soon as he had completely evacuated the primæ viæ by the use of his antimonial preparation, with which at first he used to combine some mercurial. His specification, lodged in chancery, is as follows: "Take antimony, calcine it with a continued protracted heat, in a flat, unglazed, earthen vessel adding to it from time to time a sufficient quantity of any animal oil and salt, well dephlegmated; then boil it in melted nitre for a considerable time, and separate the powder from the nitre by dissolving it in water." The real recipe has been studiously concealed, and a false one published in its stead. Different formulæ have been offered for imitating it. That of Dr. Pearson furnishes a mere mixture of an oxide of antimony, with phosphate of lime. The real powder of James, according to this chemist, consists of 57 oxide of antimony, with 43 phosphate of lime. It seems highly probable that superphosphate of lime would act on oxide of antimony, in a way somewhat similar to cream of tartar, and produce a more chemical combination, than what can be derived from a precarious ustulation and calcination of hartshorn shavings and sulphuret of antimony, in ordinary hands. The antimonial medicines are powerful deobstruents, promoting particularly the cuticular discharge. The union of this metallic oxide with sulphuretted hydrogen, ought undoubtedly to favour its medicinal agency in chronic diseases of the skin. The kermes deserves more credit than it has hitherto received from British physicians.

The compounds formed by the antimonious and antimonic acids, with the bases, have not been applied to any use. Muriate of barytes may be employed as a test for tartar emetic. It will show, by a precipitate insoluble in nitric acid, if sulphate of potash be present. If the crystals be regularly formed, mere tartar need not be suspected.*

For its ores, and the reduction of the metals, see Ores.

Ants. See Acid (Formic).

* Apatite. Phosphate of lime. This mineral occurs both massive and crystallized. The crystals are six-sided prisms, low, and sometimes passing into the six-sided table. Lateral edges, frequently truncated, and the faces smooth. Lustre splendent. Translucent, rarely transparent. Scratched by fluor spar. Brittle. Colours, white, wine-yellow, green, and red. Sp. grav. 3.1. Phosphoresces on coals. Electric by heat and friction. Consists of 53.75 lime + 46.25 phosphoric acid, by Klaproth's analysis of the variety called asparagus stone. It occurs in primitive rocks; in the tin veins of the granite of St. Michael's Mount, Cornwall; near Chudleigh in Devonshire; at Nantes in France; in St. Gothard, and in Spain; and with molybdena in granite, near Colbeck, Cumberland. *Phosphorite* is massive, forming great beds in the province of Estremadura. Yellowish-white colour. Dull or glimmering lustre. Semi-hard. Fracture, imperfect curved foliated. Brittle. Sp. grav. 2.8. Phosphorescent with heat. Its composition by Pelletier is 59 lime, 34 phosphoric acid, 1 carbonic acid, 2.5 fluoric acid, 2 silica, 1 oxide of iron, and 0.5 muriatic acid.*

* Aphrite. Earth foam; Schaumerde. This carbonate of lime occurs usually in a friable state; but sometimes solid. Colour, almost silver-white. Massive, or in fine particles. Shining lustre, between semi-metallic and pearly. Fracture, curved foliated. Opaque; soils a little. Very soft, and easily cut. Feels fine and light. It is usually found in calcareous veins, at Gera in Misnia, and Eisleben in Thuringia. It consists, by Bucholz, of 51.5 lime, 39 acid, 1 water, 5.7 silica, 3.3 oxide of iron.*

* Aplome. This is commonly consider-

ed to be a variety of the garnet; but the difference between these minerals is this: the planes of the *aplome* dodecahedrons are striated parallel with their smaller diagonal, which, according to Haüy, indicates the primitive form to be a cube, and not a dodecahedron. Its colour is deep orange-brown. It is opaque, and harder than quartz. Sp. grav. is much less than garnet, viz. 3.44. It consists, by Laugier's analysis, of 40 silica, 20 alumina, 14.5 lime, 14 oxide of iron, 2 oxide of manganese, 2 silica and iron. It is fusible into a black glass, while garnet fuses into a black enamel. It is found on the river Lena in Siberia, and also in New Holland.*

* **Apophyllite.** Ichthyophthalmite. Fisheyestone. It is found both massive and crystallized. It occurs in square prisms, whose solid angles are sometimes replaced by triangular planes, or the prisms are terminated by pyramids consisting of 4 rhomboidal planes. Structure lamellar; cross fracture, fine grained, uneven. External lustre, splendent, and peculiar; internal, glistening and pearly. Semi-transparent, or translucent. Moderately hard, and easily broken. Sp. gr. 2.49. It exfoliates, then froths, and melts into an opaque bead before the blow-pipe. It consists of 51 silica, 28 lime, 4 potash, 17 water. Vauquelin. It is found in the iron mine of Utoe in Sweden; at the copper mine of Fahlun; at Arendahl, Faroe, the Tyrol; and Dr. Mac Culloch met with a solitary crystal in Dunvegan, in the Isle of Sky.*

Apparatus. See **Laboratory.**

Apples. See **Acid (Malic).**

Apyrous. Bodies which sustain the action of a strong heat for a considerable time, without change of figure or other properties, have been called apyrous; but the word is seldom used in the art of chemistry. It is synonymous with *refractory*.

Aquafortis. This name is given to a weak and impure nitric acid, commonly used in the arts. It is distinguished by the terms *double* and *single*, the single being only half the strength of the other. The artists who use these acids call the more concentrated acid, which is much stronger even than the double aquafortis, *spirit of nitre.*. This distinction appears to be of some utility, and is therefore not improperly retained by chemical writers. See **Acid (Nitric).**

* **Aqua Marine.** See **Beryl.***

Aqua Regia, or Regis. This acid, being compounded of a mixture of the nitric and muriatic acids, is now termed by chemists nitro-muriatic acid.

Aqua Vitæ. Ardent spirit of the first distillation has been distinguished in commerce by this name. The distillers of malt and molasses spirits call it low wines.

Aquila Alba. One of the names given to the combination of muriatic acid and mercury in that state, which is more commonly known by the denomination of *mercurius dulcis, calomel,* or *mild muriate of mercury.*

Arabic (Gum). This is reckoned the purest of gums, and does not greatly differ from gum Senegal, vulgarly called gum seneca, which is supposed to be the strongest, and is on this account, as well as its greater plenty and cheapness, mostly used by calico printers and other manufacturers. The gums of the plum and cherry-tree have nearly the same qualities as gum arabic. All these substances facilitate the mixture of oils with water.

Arable Lands. It is a problem in chemistry, and by no means one of the least importance to society, to determine what are the requisites which distinguish fruitful lands from such as are less productive. See **Soils,** and **Analysis of Soils.**

Arbor Dianæ. See **Silver.**

Archil, Archilla, Rocella, Orseille. A whitish lichen, growing upon rocks in the Canary and Cape Verd Islands, which yields a rich purple tincture, fugitive indeed, but extremely beautiful. This weed is imported to us as it is gathered: those who prepare it for the use of the dyer, grind it betwixt stones, so as thoroughly to bruise, but not to reduce it into powder, and then moisten it occasionally with a strong spirit of urine, or urine itself mixed with quicklime: in a few days it acquires a purplish-red, and at length a blue colour; in the first state it is called archil, in the latter lacmus or litmus.

The dyers rarely employ this drug by itself, on account of its dearness, and the perishableness of its beauty. The chief use they make of it is for giving a bloom to other colours, as pinks, &c. This is effected by passing the dyed cloth or silk through hot water slightly impregnated with the archil. The bloom thus communicated soon decays upon exposure to the air. Mr. Hellot informs us, that by the addition of a little solution of tin, this drug gives a durable dye; that its colour is at the same time changed toward a scarlet; and that it is the more permanent, in proportion as it recedes the more from its natural colour.

Prepared archil very readily gives out its colour to water, to volatile spirits, and to alcohol; it is the substance principally made use of for colouring the spirits of thermometers. As exposure to the air destroys its colour upon cloth, the exclusion of the air produces a like effect in those hermetically sealed tubes, the spirits of large thermometers becoming in a few years colourless. The Abbé Nollet observes, (in the French Memoirs for the year 1742), that the colourless spirit, upon breaking the tube, soon resumes its colour, and this for a number of times successively; that a watery tincture of archil, included in the tubes of thermometers, lost its colour in three days; and that in an open deep vessel, it became colourless at the bottom, while the upper part retained its colour.

A solution of archil in water, applied on cold marble, stains it of a beautiful violet or purplish-blue colour, far more durable than the colour which it communicates to other bodies. M. du Fay says, he has seen pieces of marble stained with it, which in two years had suffered no sensible change. It sinks deep into the marble, sometimes above an inch, and at the same time spreads upon the surface, unless the edges be bounded by wax or some similar substance. It seems to make the marble somewhat more brittle.

There is a considerable consumption of an article of this kind, manufactured in Glasgow by Mr. Mackintosh. It is much esteemed and sold by the name of cudbear. We have seen beautiful specimens of silk thus dyed, the colours of which were said to be very permanent, of various shades, from pink and crimson to a bright mazarine blue.

Litmus is likewise used in chemistry as a test, either staining paper with it, or by infusing it in water, when it is very commonly, but with great impropriety, called *tincture of turnsole.* The persons by whom this article was prepared, formerly gave it the name of turnsole, pretending that it was extracted from the turnsole, heliotropium tricoccum, in order to keep its true source a secret. The tincture should not be too strong, otherwise it will have a violet tinge, which, however, may be removed by dilution. The light of the sun turns it red even in close vessels. It may be made with spirit instead of water. This tincture, or paper stained with it, is presently turned red by acids: and if it be first reddened by a small quantity of vinegar, or some weak acid, its blue colour will be restored by an alkali.

† Litmus gives out its colouring matter but feebly to strong alcohol; and watery infusions do not keep. To preserve it in a state for use, an infusion in weak spirit is best. †

* **Arctizite.** See Wernerite.*

Ardent Spirit. See Alcohol.

* **Arendate.** See Pistacite.*

Areometer. See Hydrometer.

Argal. Crude tartar, in the state in which it is taken from the inside of wine vessels, is known in the shops by this name.

Argentate of Ammonia, fulminating silver.

Argillaceous Earth, or Alumina.

* **Argillite.** See Clay-slate.*

Aromatics. Plants which possess a fragrant smell united with pungency, and at the same time are warm to the taste, are called aromatics. Their peculiar flavour appears to reside in their essential oil, and rises in distillation either with water or spirit.

Arrack. A spirituous liquor imported from the East Indies. It is chiefly manufactured at Batavia, and at Goa upon the Malabar coast.

* **Arragonite.** This mineral occurs massive, in fibres of a silky lustre; and in the form of fibrous branches, diverging from a centre, *Flos-ferri.* It is frequently crystallized in what appear at first sight to be regular six-sided prisms. On close inspection a longitudinal crack will be observed down each lateral face. It occurs also in elongated octohedrons. Lustre glassy, fracture foliated and fibrous. Colours greenish and pearl-gray; often violet and green in the middle; and arranged in the direction of the fibres, so that the longitudinal fibres are green, the transverse violet-blue. Double cleavage—translucent—refracts doubly—scratches calcareous spar, and sometimes even glass—brittle—sp. grav. 2.90. It consists of carbonate of lime, with occasionally a little carbonate of strontites. It is found in Arragon in Spain, at Leogany in Salzburg, at Marienberg in Saxony, and Sterzing in the Tyrol. In the cavities of Basalt near Glasgow. The finest specimens of Flos-ferri ramifications, come from the mines of Eisenerz in Stiria. Beautiful specimens have been also found in the Dufton lead mines in England, in the workings of an old coal mine, called Luftonhill pit near Durham. It also occurs in the trap rocks of Scotland.*

Arsenic, in the metallic state, is of a bluish white colour, subject to tarnish, and grows first yellowish, then black, by exposure to air. It is brittle, and when broken exhibits a laminated texture. Its specific gravity is 5.763. In close vessels it sublimes entire at 356° F. but burns with a small flame if respirable air be present.

The arsenic met with in commerce has the form of a white oxide. It is brought chiefly from the cobalt works in Saxony, where zaffre is made. Cobalt ores contain much arsenic, which is driven off by long torrefaction. The ore is thrown into a furnace resembling a baker's oven, with a flue, or horizontal chimney, nearly two hundred yards long, into which the fumes pass, and are condensed into a grayish or blackish powder. This is refined by a second sublimation in close vessels, with a little potash, to detain the impurities. As the heat is considerable, it melts the sublimed flowers into those crystalline masses which are met with in commerce. See Acid (Arsenious).

The metal may be obtained from this, either by quickly fusing it together with twice its weight of soft soap and an equal quantity of alkali, and pouring it out, when fused, into a hot iron cone; or by mixing it in powder with oil, and exposing it in a matrass to a sand heat. This process is too offensive to be performed, except in the open air, or where a current of air carries off the fumes. The decomposed oil first rises; and the arsenic is afterwards sublimed, in the form of a flaky metallic substance. It may likewise be obtained by mixing two parts of the arsenious acid with one of black flux; putting the mixture into a crucible, with another inverted over it, and luted to it with clay and sand; and applying a red heat to the lower crucible. The metal will be reduced, and line the inside of the upper crucible.

It is among the most combustible of the metals, burns with a blue flame, and garlic smell, and sublimes in the state of arsenious acid.

† A very striking characteristic of this metal is, that it sublimes before it fuses.†

Concentrated sulphuric acid does not attack arsenic when cold; but if it be boiled upon this metal, sulphurous acid gas is emitted, a small quantity of sulphur sublimes, and the arsenic is reduced to an oxide.

Nitrous acid readily attacks arsenic, and converts it into arsenious acid, or, if much be employed, into arsenic acid.

Boiling muriatic acid dissolves arsenic, but affects it very little when cold. This solution affords precipitates upon the addition of alkalis. The addition of a little nitric acid expedites the solution; and this solution, first heated and condensed in a close vessel, is wholly sublimed into a thick liquid, formerly termed *butter of arsenic*. Thrown in powder into chlorine gas, it burns with a bright white flame, and is converted into a chloride.

None of the earths or alkalis act upon it, unless it be boiled a long while in fine powder, in a large proportion of alkaline solution.

Nitrates detonate with arsenic, convert it into arsenic acid, and this, combining with the base of the nitrate, forms an arseniate, that remains at the bottom of the vessel.

Muriates have no action upon it; but if three parts of chlorate of potash be mixed with one part of arsenic in fine powder, which must be done with great precaution, and a very light hand, a very small quantity of this mixture, placed on an anvil, and struck with a hammer, will explode with flame and a considerable report; if touched with fire, it will burn with considerable rapidity; and if thrown into concentrated sulphuric acid, at the instant of contact a flame rises into the air like a flash of lightning, which is so bright as to dazzle the eye.

Arsenic readily combines with sulphur by fusion and sublimation, and forms a yellow compound called *orpiment*, or a red called *realgar*. The nature of these, and their difference, are not accurately known, but Fourcroy considers the first as a combination of sulphur with the oxide, and the second as a combination of sulphur with the metal itself, as he found the red sulphuret converted into the yellow by the action of acids.

Arsenic is soluble in fat oils in a boiling heat; the solution is black, and has the consistence of an ointment when cold. Most metals unite with arsenic; which exists in the metallic state in such alloys as possess the metallic brilliancy.

* Iodine and arsenic unite, forming an iodide of a dark purple-red colour, possessing the properties of an acid. It is soluble in water, and its solution forms a soluble compound with potash. Arsenic combines with hydrogen into a very noxious compound, called arsenuretted hydrogen gas. To prepare it, fuse in a covered crucible, 3 parts of granulated tin, and 1 of metallic arsenic in powder; and submit this alloy, broken in pieces, to the action of muriatic acid in a glass retort. On applying a moderate heat, the arsenuretted hydrogen comes over, and may be received in a mercurial or water pneumatic trough. Protomuriate of tin remains in the retort. When 1 of arsenic is used for 15 of tin, the former metal is entirely carried off in the evolved hydrogen. 100 parts of this gas contain 140 of hydrogen, as is proved by heating it with tin. Its specific gravity, according to Sir H. Davy, is 0.5552; according to Trommsdorf, 0.5293. Stromeyer states, that by a cold of — 22°, it condenses into a liquid. Exploded with twice its bulk of oxygen, water and oxide of arsenic are formed. When arsenuretted hydrogen issuing from a tube is set on fire, it deposites a hydruret of arsenic. Sulphur, potassium, sodium, and tin, decompose this gas, combine with its metal, and in the case of sulphur, sulphuretted hydrogen results. By subtracting from the specific gravity of the arsenuretted gas, that of hydrogen gas $\frac{140}{100}$, we have the proportion of arsenic present; $0.55520 - 0.09716 = 0.45804$ = the arsenic in 100 measures of arsenuretted hydrogen; which gives the proportion by weight of about 6 arsenic to 1 hydrogen; but Stromeyer's

analysis by nitric acid gives about 50 arsenic to 1 hydrogen, which is probably much nearer the true composition. A prime equivalent of hydrogen is to one of arsenic as 1 to 76; and 2 consequently as 1 to 38. Gehlen fell a victim to his researches on this gas; and therefore the new experiments requisite to elucidate its constitution must be conducted with circumspection. If chlorine be added to a mixture of arsenuretted and sulphuretted hydrogen, the bulk diminishes, and yellow coloured flakes are deposited. Concentrated nitric acid occasions an explosion in this gas, preceded by nitrous fumes; but if the acid be diluted, a silent decomposition of the gas is effected. The density of the hydrogen in this compound gas is 0.09716. Therefore, by Stromeyer's analysis, we have this proportion to calculate the specific gravity of the gas, $2.19 : 0.09716 :: (2.19 + 106) : 4.827$; a quantity nearly 9 times greater than what experiment has given.

This gas extinguishes flame, and instantly destroys animal life. Water has no effect upon it. From the experiments of Sir H. Davy and MM. Gay-Lussac and Thenard, there appears to be a solid compound of hydrogen and arsenic, or a hydruret. It is formed by acting with the negative pole of a voltaic battery on arsenic plunged in water. It is reddish-brown, without lustre, taste, and smell. It is not decomposed at a heat approaching to cherry-red; but at this temperature it absorbs oxygen; while water and arsenious acid are formed, with the evolution of heat and light. The proportion of the two constituents is not known.*

Arsenic is used in a variety of arts. It enters into metallic combinations, wherein a white colour is required. Glass manufacturers use it; but its effect in the composition of glass does not seem to be clearly explained. Orpiment and realgar are used as pigments. See Acids (Arsenic, and Arsenious).

Asafœtida is obtained from a large umbelliferous plant growing in Persia. The root resembles a large parsnep externally, of a black colour: on cutting it transversely, the assafœtida exudes in form of a white thick juice, like cream; which, from exposure to the air, becomes yellower and yellower, and at last of a dark-brown colour. It is very apt to run into putrefaction; and hence those who collect it carefully defend it from the sun. The fresh juice has an excessively strong smell, which grows weaker and weaker upon keeping: a single dram of the fresh fluid juice smells more than a hundred pounds of the dry assafœtida brought to us. The Persians are commonly obliged to hire ships on purpose for its carriage, as scarcely any one will receive it along with other commodities, its stench infecting every thing that comes near it.

The common asafœtida of the shops is of a yellowish or brownish colour, unctuous and tough, of an acrid or biting taste, and a strong disagreeable smell, resembling that of garlic. From four ounces Neumann obtained, by rectified spirit, two ounces six drams and a half of resinous extract; and afterward, by water, three drams and half a scruple of gummy extract; about six drams and a scruple of earthy matter remaining undissolved. On applying water at first, he gained, from four ounces, one ounce three scruples and a half of gummy extract.

Asafœtida is administered in nervous and hysteric affections, as a deobstruent, and sometimes as an anthelmintic. A tincture of it is kept in the shops, and it enters into the composition of the compound galbanum pill of the London college, the gum pill of former dispensatories.

* **Asbestos or Asbestus.** A mineral of which there are five varieties, all more or less flexible and fibrous.

1. *Amianthus* occurs in very long, fine, flexible, elastic fibres, of a white, greenish, or reddish colour. It is somewhat unctuous to the touch, has a silky or pearly lustre, and is slightly translucent. Sectile; tough; sp. grav. from 1 to 2.3. Melts with difficulty before the blow-pipe, into a white enamel. It is usually found in serpentine; in the Tarentaise in Savoy; in long and beautiful fibres, in Corsica; near Barèges, in the Pyrenees; in Dauphiny and St. Gothard; at St. Keverne, Cornwall; at Portsoy, Scotland; in mica slate at Glenelg, Invernesshire, and near Durham. It consists of 59 silex, 25 magnesia, 9.5 lime, 3 alumina, and 2.25 oxide of iron.*

The ancients manufactured cloth out of the fibres of asbestos, for the purpose, it is said, of wrapping up the bodies of the dead, when exposed on the funeral pile. Several moderns have likewise succeeded in making this cloth; the chief artifice of which seems to consist in the admixture of flax and a liberal use of oil; both which substances are afterwards consumed by exposing the cloth for a certain time to a red heat. Although the cloth of asbestos, when soiled, is restored to its primitive whiteness by heating in the fire; it is found, nevertheless, by several authentic experiments, that its weight diminishes by such treatment. The fibres of asbestos, exposed to the violent heat of the blowpipe, exhibit slight indications of fusion; though the parts, instead of running together, moulder away, and part fall down, while the rest seem to disappear before the current of air. Ignition impairs the flexibility of asbestos in a slight degree.

* 2. *Common Asbestus* occurs in masses of fibres of a dull greenish colour, and of a somewhat pearly lustre. Fragments splintery. It is scarcely flexible, and greatly denser than amianthus. It is slightly unctuous to the touch. Sp. grav. 2.7. Fuses with difficulty into a grayish-black scoria. It is composed of 63.9 silica, 16 magnesia, 12.8 lime, 6 oxide of iron, and 1.1 alumina. It is more abundant than amianthus, and is found usually in serpentine, as at Portsoy, the Isle of Anglesea, and the Lizard in Cornwall. It was found in the limestone of Glentilt, by Dr. M'Culloch, in a pasty state, but it soon hardened by exposure to air.

3. *Mountain Leather* consists not of parallel fibres like the preceding, but interwoven and interlaced so as to become tough. When in very thin pieces it is called *mountain paper*. Its colour is yellowish-white, and its touch meagre. It is found at Wanlockhead, in Lanarkshire. Its specific gravity is uncertain.

4. *Mountain Cork, or Elastic Asbestus,* is, like the preceding, of an interlaced fibrous texture; is opaque, has a meagre feel and appearance, not unlike common cork, and like it too, is somewhat elastic. It swims on water. Its colours are, white, gray, and yellowish-brown. Receives an impression from the nail; very tough; cracks when handled, and melts with difficulty before the blow-pipe. Sp. grav. from 0.68 to 0.99. It is composed of silica 62, carbonate of lime 12, carbonate of magnesia 23, alumina 2.8, oxide of iron 3.

5. *Mountain Wood.* Ligniform asbestus. Is usually massive, of a brown colour, and having the aspect of wood. Internal lustre glimmering. Soft, sectile and tough; opaque; feels meagre; fusible into a black slag. Sp. grav. 2.0. It is found in the Tyrol; Dauphiny; and in Scotland, at Glentilt, Portsoy, and Kildrumie.*

Ashes. The fixed residue of combustible substances, which remains after they have been burned, is called ashes. In chemistry it is most commonly used to denote the residue of vegetable combustion.

* **Asparagin.** White transparent crystals, of a peculiar vegetable principle, which spontaneously form in asparagus juice which has been evaporated to the consistence of sirup. They are in the form of rhomboidal prisms, hard and brittle, having a cool and slightly nauseous taste. They dissolve in hot water, but sparingly in cold water, and not at all in alcohol. On being heated they swell, and emit penetrating vapours, which affect the eyes and nose like wood-smoke. Their solution does not change vegetable blues; nor is it affected by hydrosulphuret of potash, oxalate of ammonia, acetate of lead, or infusion of galls. Lime disengages ammonia from it; though none is evolved by triturating it with potash. The asparagus juice should be first heated to coagulate the albumen, then filtered and left to spontaneous evaporation for 15 or 20 days. Along with the asparagin crystals, others in needles of little consistency appear, analogous to *mannite*, from which the first can be easily picked out. Vauquelin and Robiquet. Annales de Chimie, vol. 55. and Nicholson's Journal, 15.*

Asphaltum. This substance, likewise called Bitumen Judaicum, or Jews' Pitch, is a smooth, hard, brittle, black or brown substance, which breaks with a polish, melts easily when heated, and when pure burns without leaving any ashes. It is found in a soft or liquid state on the surface of the Dead Sea,§ but by age grows dry and hard. The same kind of bitumen is likewise found in the earth in other parts of the world; in China; America, particularly in the island of Trinidad; and some parts of Europe, as the Carpathian hills, France, Neufchattel, &c. Its specific gravity, according to Boyle, is 1.400, to Kirwan, from 1.07 to 1.65. A specimen from Albania, of the specific gravity of 1.205, examined by Mr. Klaproth, was found to be soluble only in oils and in ether. Five parts of rectified oil of petroleum dissolved one of the asphaltum, without heat, in 24 hours. Analyzed in the dry way, 100 grains afforded 32 of bituminous oil, 6 of water faintly ammoniacal, 30 of charcoal, 7½ of silex, 7½ of alumina, ¾ of lime, 1¼ oxide of iron, ½ oxide of manganese, and 36 cubic inches of hydrogen gas.

According to Neumann, the asphaltum of the shops is a very different compound from the native bitumen; and varies, of course, in its properties, according to the nature of the ingredients made use of in forming it. On this account, and probably from other reasons, the use of asphaltum, as an article of the materia medica, is almost totally laid aside.

* The Egyptians used asphaltum in embalming, under the name of mumia mineralis, for which it is well adapted. It was used for mortar at Babylon.*

Assay, *or* **Essay.** This operation consists in determining the quantity of valuable or precious metal contained in any mineral or metallic mixture, by analyzing a small part thereof. The practical difference between the analysis and the assay of an ore, consists in this: The analysis, if properly made, determines the nature and quantities of all the parts of the compound; whereas, the object of the assay consists in ascertaining how much of the particular metal in question may be contained in a certain determinate quantity of the material under examination. Thus, in the assay of gold or silver, the baser metals are considered as of no value or consequence; and the problem to be resolved is simply, how much of each is contained in the ingot or piece of metal intended to be assayed. The examination of metallic ores may be seen under their respective titles; the present article will therefore consist of an account of the assaying of gold and silver.

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§ In the Mem. of the Academy of Sciences of Paris for 1778, there is an analysis of the water of this sea by Messrs. Macquer, Lavoisier, and Sage; by which it appears to contain 22 per cent of muriate of magnesia, 16½ of muriate of lime, and 6½ of muriate of soda. Its specific gravity is 1.25. It is limpid, and without smell.

To obtain gold or silver in a state of purity, or to ascertain the quantity of alloy it may contain, it is exposed to a strong heat, together with lead, in a porous crucible. This operation is called cupellation, and is performed as follows: The precious metal is put, together with a due proportion of lead, into a shallow crucible, made of burned bones, called a cupel; and the fusion of the metals is effected by exposing them to a considerable heat in a muffle, or small earthen oven, fixed in the midst of a furnace. The lead continually vitrifies, or becomes converted into a glassy calx, which dissolves all the imperfect metals. This fluid glass, with its contents, soaks into the cupel, and leaves the precious metals in a state of purity. During the cupellation, the scoriæ running down on all sides of the metallic mass, produce an appearance called circulation; by which the operator judges whether the process be going on well. When the metal is nearly pure, certain prismatic colours flash suddenly across the surface of the globule, which soon afterwards appears very brilliant and clean: this is called the brightening, and shows that the separation is ended.

After gold has passed the cupel, it may still contain either of the other perfect metals, platina, or silver. The former is seldom suspected; the latter is separated by the operations called quartation and parting. Quartation consists in adding three parts of silver to the supposed gold, and fusing them together; by which means the gold becomes at most one-fourth of the mass only. The intention of this is to separate the particles of gold from each other, so that they may not cover and defend the silver from the action of the nitric acid, which is to be used in the process of parting. Parting consists in exposing the mass, previously hammered or rolled out thin, to the action of seven or eight times its weight of boiling nitric acid of a due strength. The first portion of nitric acid being poured off, about half the quantity, of a somewhat greater strength, is to be poured on the remaining gold; and if it be supposed that this has not dissolved all the silver, it may even be repeated a second time. For the first operation an acid of the specific gravity of 1.280 may be used, diluted with an equal quantity of water; for the second, an acid about 1.26 may be taken undiluted. If the acid be not too concentrated, it dissolves the silver, and leaves the gold in a porous mass, of the original form; but, if too strong, the gold is in a powdery form, which may be washed and dried. The weight of the original metal before cupellation, and in all the subsequent stages, serves to ascertain the degree of fineness of the ingot, or ore, of which it is a part.

In estimating or expressing the fineness of gold, the whole mass spoken of is supposed to weigh twenty-four carats of twelve grains each, either real, or merely proportional, like the assayer's weights; and the pure gold is called fine. Thus, if gold be said to be 23 carats fine, it is to be understood, that, in a mass weighing 24 carats, the quantity of pure gold amounts to 23 carats.

In such small works as cannot be assayed by scraping off a part, and cupelling it, the assayers endeavour to ascertain its quality or fineness by the touch. This is a method of comparing the colour, and other properties of a minute portion of the metal, with those of small bars, the composition of which is known. These bars are called touch-needles; and they are rubbed upon the black basaltes, which, for this reason, is called the touchstone. Black flint or pottery will serve the same purpose. Sets of gold needles may consist of—pure gold; pure gold 23½ carats, with half a carat of silver; 23 carats of gold, with one carat of silver; 22½ carats of gold, with 1½ carats of silver; and so on, till the silver amounts to four carats; after which the additions may proceed by whole carats. Other needles may be made in the same manner, with copper instead of silver; and other sets may have the addition consisting either of equal parts silver and copper, or such proportions as the occasions of business require. The examination by the touch may be advantageously employed previous to quartation, to indicate the quantity of silver necessary to be added.

In foreign countries, where trinkets and small work are required to be submitted to the assay of the touch, a variety of needles are necessary; but they are not much used in England. They afford, however, a degree of information, which is more considerable than might at first be expected. The attentive assayer not only compares the colour of the stroke made upon the touchstone by the metal under examination, with that produced by his needle; but will likewise attend to the sensation of roughness, dryness, smoothness, or greasiness, which the texture of the rubbed metal excites, when abraded by the stone. When two strokes, perfectly alike in colour, are made upon the stone, he may then wet them with aquafortis, which will affect them very differently, if they be not similar compositions; or the stone itself may be made red-hot by the fire, or by the blow-pipe, if thin black pottery be used; in which case the phenomena of oxidation will differ, according to the nature and quantity of the alloy.

The French government has from time to time caused various experimental inquiries to be made respecting the art of assaying gold, which have thrown much light on this subject, and greatly tend to produce uniformity in the results of the operation. The latest report on this subject may be seen in the Annales de Chimie, vol. vi. p. 64.; which may be consulted for a full account of the experiments and history of former proceedings. The general result is as follows, nearly in the words of the authors:

Six principal circumstances appear to affect the operation of parting: namely, the quantity of acid used in parting, or in the first boiling; the concentration of this acid; the time employed in its application; the quantity of acid made use of in the reprise, or second operation; its concentration; and the time during which it is applied. From the experiments it has been shown, that each of these unfavourable circumstances might easily occasion a loss of from the half of a thirty-second part of a carat, or two thirty-second parts. The writers explain their technical language by observing, that, the whole mass consisting of twenty-four carats, this thirty-second part denotes 1-768th part of the mass. It may easily be conceived, therefore, that if the whole six circumstances were to exist, and be productive of errors falling the same way, the loss would be very considerable.

It is therefore indispensibly necessary, that one uniform process should be followed in the assays of gold; and it is a matter of astonishment, that such an accurate process should not have been prescribed by Government for assayers in an operation of such great commercial importance, instead of every one being left to follow his own judgment. The process recommended in the report before us is as follows:—

Twelve grains of the gold intended to be assayed must be mixed with thirty grains of fine silver, and cupelled with 108 grains§ of lead. The cupellation must be carefully attended to, and all the imperfect buttons rejected. When the cupellation is ended, the button must be reduced by lamination into a plate of 1½ inch, or rather more, in length, and four or five lines in breadth. This must be rolled up upon a quill, and placed in a matrass capable of holding about three ounces of liquid, when filled up to its narrow part. Two ounces and a half of very pure aquafortis, of the strength of 20 degrees of Baumé's areometer, must then be poured upon it; and the matrass being placed upon hot ashes or sand, the acid must be kept gently boiling for a quarter of an hour; the acid must then be cautiously decanted and an additional quantity of 1½ ounce, must be poured on the metal, and slightly boiled for twelve minutes. This being likewise carefully decanted, the small spiral piece of metal must be washed with filtered river water, or distilled water, by filling the matrass with this fluid. The vessel is then to be reversed, by applying the extremity of its neck against the bottom of a crucible of fine earth, the internal surface of which is very smooth. The annealing must then be made, after having separated the portion of water which had fallen into the crucible; and, lastly the annealed gold must be weighed. For the certainty of this operation, two assays must be made in the same manner, together with a third assay upon gold of twenty-four carats, or upon gold the fineness of which is perfectly and generally known.

No conclusion must be drawn from this assay, unless the latter gold should prove to be of the fineness of twenty-four carats exactly, or of its known degree of fineness; for if there be either loss or surplus, it may be inferred that the other two assays, having undergone the same operation, must be subject to the same error. The operation being made according to this process, by several assayers, in circumstances of importance, such as those which relate to large fabrications, the fineness of the gold must not be depended on, nor considered as accurately known, unless all the assayers have obtained a uniform result, without communication with each other. The authors observe, however, that this identity must be considered as existing to the accuracy of half of the thirty-second part of a carat. For notwithstanding every possible precaution or uniformity, it very seldom happens that an absolute agreement is obtained between the different assays of one and the same ingot, because the ingot itself may differ in its fineness in different parts of its mass.

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§ 1½ gross. Though these doses of silver and lead appeared to be proper for all operations of assaying gold, the commissaries observe, nevertheless, that gold of a lower title than eighteen carats may be alloyed with two parts, and even less, of silver; in order that the small mass of metal, when it comes to be laminated, may not be too thin, so as to break in pieces during the parting.

The assaying of silver does not differ from that of gold, excepting that the parting operation is not necessary. A certain small portion of the silver is absorbed by the cupel, and the more when a larger quantity of lead is used, unless the quantity of lead be excessive; in which case most of it will be scorified before it begins to act upon the silver. Messrs. Hellot, Tillet, and Macquer, from their experiments made by order of the French Government, have ascertained, that four parts of lead are requisite for silver of eleven pennyweights twelve grains fine, or containing this weight of pure silver, and twelve grains of alloy, in twelve pennyweights; six parts of lead for silver of eleven pennyweights; eight parts of lead for silver of ten pennyweights; ten parts of lead for silver of nine pennyweights; and so on in the same progression.

Astringent Principle. The effect called astringency, considered as distinguishable by the taste, is incapable of being defined. It is perceived in the husks of nuts, of walnuts, in green tea, and eminently in the nut-gall. This is probably owing to the circumstance, that acids have likewise the property of corrugating the fibres of the mouth and tongue, which is considered as characteristic of astringency as it relates to taste; and hence the gallic acid, which is commonly found united with the true astringent principle, was long mistaken for it. Seguin first distinguished them, and, from the use of this principle in tanning skins, has given it the name of *tannin*. Their characteristic differences are, the gallic acid forms a black precipitate with iron; the astringent principle forms an insoluble compound with albumen. See Tannin.

Athanor. A kind of furnace, which has long since fallen into disuse. The very long and durable operations of the ancient chemists rendered it a desirable requisite, that their fires should be constantly supplied with fuel in proportion to the consumption. The athanor furnace was peculiarly adapted to this purpose. Beside the usual parts, it was provided with a hollow tower, into which charcoal was put. The upper part of the tower, when filled, was closely shut by a well-fitted cover; and the lower part communicated with the fire-place of the furnace. In consequence of this disposition, the charcoal subsided into the fire-place gradually as the consumption made room for it; but that which was contained in the tower was defended from combustion by the exclusion of a proper supply of air.

* **Atmometer.** The name of an instrument contrived by Professor Leslie, to measure the quantity of exhalation from a humid surface in a given time. It consists of a thin ball of porous earthen-ware, two or three inches in diameter, with a small neck, to which is firmly cemented a long and rather wide tube of glass, bearing divisions, each of them corresponding to an internal annular section, equal to a film of liquid that would cover the outer surface of the ball to the thickness of the thousandth part of an inch. These divisions are ascertained by a simple calculation, and numbered downwards to the extent of 100 or 200. To the top of the tube is fitted a brass cap, having a collar of leather, and which, after the cavity has been filled with distilled or boiled water, is screwed tight. The outside of the ball being now wiped dry, the instrument is suspended out of doors, and exposed to the free action of the air. The quantity of evaporation from a wet ball is the same as from a circle having twice the diameter of the sphere. In the atmometer, the humidity transudes through the porous substance, just as fast as it evaporates from the external surface; and this waste is measured by the corresponding descent of water in the stem. At the same time, the tightness of the collar taking off the pressure of the column of liquid, prevents it from oozing so profusely as to drop from the ball; an inconvenience which, in the case of very feeble evaporation, might otherwise take place. As the process goes on, a corresponding portion of air is likewise imbibed by the moisture on the outside, and being introduced into the ball, rises in a small stream to replace the water. The rate of evaporation is nowise affected by the quality of the porous ball. It continues exactly the same when the exhaling surface appears almost dry, as when it glistens with superfluous moisture. When the consumption of water is excessive, it may be allowed to percolate by unscrewing the cap, taking care, however, to let no drops fall.* *Leslie on Heat and Moisture.*

Atmosphere. See Air (Atmospherical).

* **Atomic Theory.** See Equivalents (Chemical).*

* **Atropia.** A new vegetable alkali, extracted by Dr. Brandes from the *Atropa*

belladonna, or deadly nightshade. It is white, brilliant, crystallizes in long needles, is tasteless, and little soluble in water or alcohol. It resists a moderate heat. With acids, it forms regular salts, and is capable of neutralizing a considerable proportion of acid. Sulphate of atropia is composed of,

Sulphuric acid,	36.52	5.00
Atropia,	38.93	5.33
Water,	24.55	
	100.00,*	

Attraction. The instances of attraction which are exhibited by the phenomena around us, are exceedingly numerous, and continually present themselves to our observation. The effect of gravity, which causes the weight of bodies, is so universal, that we can scarcely form an idea how the universe could subsist without it. Other attractions, such as those of magnetism and electricity, are likewise observable; and every experiment in chemistry tends to show, that bodies are composed of various principles or substances, which adhere to each other with various degrees of force, and may be separated by known methods. It is a question among philosophers, whether all the attractions which obtain between bodies be referable to one general cause modified by circumstances; or whether various original and distinct causes act upon the particles of bodies at one and the same time. The philosophers at the beginning of the present century were disposed to consider the several attractions as essentially different, because the laws of their action differ from each other; but the moderns appear disposed to generalize this subject, and to consider all the attractions which exist between bodies, or at least those which are permanent, as depending upon one and the same cause, whatever it may be, which regulates at once the motions of the immense bodies that circulate through the celestial spaces, and those minute particles that are transferred from one combination to another in the operations of chemistry. The earlier philosophers observed, for example, that the attraction of gravitation acts upon bodies with a force which is inversely as the squares of the distances; and from mathematical deduction they have inferred, that the law of attraction between the particles themselves follows the same ratio; but when their observations were applied to bodies very near each other, or in contact, an adhesion took place, which is found to be much greater than could be deduced from that law applied to the centres of gravity. Hence they concluded, that the cohesive attraction is governed by a much higher ratio, and probably the cubes of the distances. The moderns, on the contrary, among whom are Bergmann, Guyton-Morveau, and others, have remarked, that these deductions are too general, because, for the most part, drawn from the consideration of spherical bodies, which admit of no contact but such as is indefinitely small, and exert the same powers on each other, whichever side may be obverted. They remark, likewise, that the consequence depending on the sum of the attractions in bodies not spherical, and at minute distances from each other, will not follow the inverted ratio of the square of the distance taken from any point assumed as the centre of gravity, admitting the particles to be governed by that law; but that it will greatly differ, according to the sides of the solid which are presented to each other, and their respective distances; insomuch that the attractions of certain particles indefinitely near each other will be indefinitely increased, though the ratio of the powers acting upon the remoter particles may continue nearly the same.

This doctrine, which however requires to be much more strictly examined by the application of mathematical principles, obviously points to a variety of interesting consequences. The polarity of particles, or their disposition to present themselves in their approach to each other in certain aspects, though it has been treated as a chimerical notion by a few writers, is one of the first of these results.

These are speculations, which, with regard to the present state of chemistry, stand in much the same situation as the theory of gravity, which is minutely described in Plutarch, did with regard to astronomy before the time of Newton. As the celestial phenomena were formerly arranged from observation merely, but are now computed from the physical cause, gravitation; so, at present, chemistry is the science of matter of fact duly arranged, without the assistance of any extensive theory immediately deduced from the figures, volumes, densities, or mutual actions of the particles of bodies. What it may hereafter be, must depend on the ability and research of future chemists; but at present we must dismiss this remoter part of theory, to attend more immediately to the facts.

That the parts of bodies do attract each other, is evident from that adhesion which produces solidity, and requires a certain force to overcome it. For the sake of perspicuity, the various effects of attraction have been considered as different kinds of affinity or powers. That power which physical writers call the attraction of cohesion, is generally called the attraction of aggregation by chemists. Aggregation is considered as the adhesion of parts of the same kind. Thus a number of pieces of brimstone united by fusion, form an aggregate, the parts of which may be separated again by mechanical means. These parts have been called integrant parts; that is to say, the minutest parts into which a body can be divided, either really or by the imagination, so as not to change its nature, are called integrant parts. Thus, if sulphur and an alkali be combined together, and form liver of sulphur, we may conceive the mass to be divided and subdivided to an extreme degree, until at length the mass consists of merely a particle of brimstone and a paricle of alkali. This then is an integrant part; and if it be divided further, the effect which chemists call decomposition will take place; and the particles consisting no longer of liver of sulphur, but of sulphur alone, and alkali alone, will be what chemists call component parts or principles.

The union of bodies in a gross way is called mixture. Thus sand and an alkali may be mixed together. But when the very minute parts of a body unite with those of another so intimately as to form a body, which has properties different from those of either of them, the union is called combination, or composition. Thus, if sand and an alkali be exposed to a strong heat, the minute parts of the mixture combine, and form glass.

The earlier chemists were very desirous of ascertaining the first principles, or elements of bodies; and they distinguished by this name such substances as their art was incapable of rendering more simple. They seem however to have overlooked the obvious circumstance, that the limits of art are not the limits of nature. At present we hear little concerning elements. Those substances which we have not hitherto been able to analyze, or which, if decomposed, have hitherto eluded the observation of chemists, are indeed considered as simple substances relative to the present state of our knowledge, but in no other respect; for a variety of experiments give us reason to hope, that future enquiries may elucidate their nature and composition. Some writers, calling these simple substances by the name of Primary Principles, have distinguished compounds of these by the name of Secondary Principles, which they suppose to enter again into combinations without decomposition or change. It must be confessed, nevertheless, that no means have yet been devised to show whether any such subordination of principles exists. We may indeed discover that a compound body consists of three or more principles; but whether two of these be previously united, so as to form a simple substance with relation to the third, or what in other respects may be their arrangement, we do not know. That it does exist, however, seems clear by making combinations in varied orders. Thus a weak solution of alkali will not dissolve oil; but a combination of oil and alkali will not separate by the addition of water. The alkali therefore adheres to that with which it was first combined. See also the article Vegetables.

If two solid bodies, disposed to combine together, be brought into contact with each other, the particles which touch will combine, and form a compound; and if the temperature at which this new compound assumes the fluid form be higher than the temperature of the experiment, the process will go no further, because this new compound being interposed between the two bodies, will prevent their further access to each other; but if, on the contrary, the freezing point of the compound be lower than this temperature, liquefaction will ensue; and the fluid particles being at liberty to arrange themselves according to the law of their attractions, the process will go on, and the whole mass will gradually be converted into a new compound in the fluid state. An instance of this may be exhibited by mixing common salt and perfectly dry pounded ice together. The crystals of the salt alone will not liquefy unless very much heated; the crystals of the water, that is to say, the ice, will not liquefy unless heated as high as thirty-two degrees of Fahrenheit; and we have of course supposed the temperature of the experiment to be lower than this, because our water is in the solid state. Now it is a well known fact, that brine, or the saturated solution of sea salt in water, cannot be frozen unless it be cooled thirty-eight degrees lower than the freezing point of pure water. It follows then, that, if the temperature of the experiment be higher than this, the first combinations of salt and ice will produce a fluid brine, and the combination will proceed until the temperature of the mass has gradually sunk as low as the freezing point of brine; after which it would cease, if it were not that surrounding bodies continually tend to raise the temperature. And accordingly it is found by experiment, that, if the ice and the salt be previously cooled below the temperature of freezing brine, the combination and liquefaction will not take place. See Caloric.

The instances in which solid bodies thus combine together not being very numerous, and the fluidity which ensues immediately after the commencement of this kind of experiment, have induced several chemists to consider fluidity in one or both of the bodies applied to each other, to be a necessary circumstance, in order that they may produce chemical action upon each other. *Corpora non agunt nisi sint fluida.*

If one of two bodies applied to each other be fluid at the temperature of the experiment, its parts will successively unite with the parts of the solid, which will by that means be suspended in the fluid, and disappear. Such a fluid is called a solvent or menstruum; and the solid body is said to be dissolved.

Some substances unite together in all proportions. In this way the acids unite with water. But there are likewise many substances which cannot be dissolved in a fluid, at a settled temperature, in any quantity beyond a certain proportion. Thus, water will dissolve only about one-third of its weight of common salt; and if more salt be added, it will remain solid. A fluid which holds in solution as much of any substance as it can dissolve, is said to be saturated with it. But saturation with one substance is so far from preventing a fluid from dissolving another body, that it very frequently happens, that the solvent power of the compound exceeds that of the original fluid itself. Chemists likewise use the word saturation in another sense; in which it denotes, such a union of two bodies as produces a compound the most remote in its properties from the properties of the component parts themselves. In combinations where one of the principles predominates, the one is said to be supersaturated, and the other principle is said to be subsaturated.

Heat in general increases the solvent power of fluids, probably by preventing part of the dissolved substance from congealing, or assuming the solid form.

It often happens, that bodies which have no tendency to unite are made to combine together by means of a third, which is then called the medium. Thus, water and fat oils are made to unite by the medium of an alkali, in the combination called soap. Some writers, who seem desirous of multiplying terms, call this tendency to unite the *affinity of intermedium.* This case has likewise been called *disposing affinity;* but Berthollet more properly styles it *reciprocal affinity.* He likewise distinguishes affinity into *elementary,* when it is between the elementary parts of bodies; and *resulting,* when it is to a compound only, and would not take place with the elements of that compound.

It very frequently happens, on the contrary, that the tendency of two bodies to unite, or remain in combination together, is weakened or destroyed by the addition of a third. Thus, alcohol unites with water in such a manner as to separate most salts from it. A striking instance of this is seen in a saturated or strong solution of nitre in water. If to this there be added an equal measure of alcohol, the greater part of the nitre instantly falls down. Thus magnesia is separated from a solution of Epsom salt, by the addition of an alkali, which combines with the sulphuric acid, and separates the earth. The principle which falls down is said to be precipitated, and in many instances is called a precipitate. Some modern chemists use the term precipitation in a more extended, and rather forced sense; for they apply it to all substances thus separated. In this enunciation, therefore, they would say, that potash precipitates soda from a solution of common salt, though no visible separation or precipitation takes place; for the soda, when disengaged from its acid, is still suspended in the water by reason of its solubility.

From a great number of facts of this nature, it is clearly ascertained, not as a probable hypothesis, but as simple matter of fact, that some bodies have a stronger tendency to unite than others; and that the union of any substance with another will exclude, or separate, a third substance, which might have been previously united with one of them; excepting only in those cases wherein the new compound has a tendency to unite with that third substance, and form a triple compound. This preference of uniting, which a given substance is found to exhibit with regard to other bodies, is by an easy metaphor called elective attraction, and is subject to a variety of cases, according to the number and the powers of the principles which are respectively presented to each other. The cases which have been most frequently observed by chemists, are those called simple elective attractions, and double elective attractions.

When a simple substance is presented or applied to another substance compounded of two principles, and unites with one of these two principles so as to separate or exclude the other, this effect is said to be produced by simple elective attraction.

It may be doubted whether any of our operations have been carried to this degree of simplicity. All the chemical principles we are acquainted with are simple only with respect to our power of decomposing them; and the daily discoveries of our contemporaries tend to decompose those substances, which chemists a few years ago considered as simple. Without insisting, however, upon this difficulty, we may observe, that water is concerned in all the operations which are called humid, and beyond a doubt modifies all the effects of such bodies as are suspended in it; and the variations of temperature, whether arising from an actual igneous fluid, or from a mere modification of the parts of bodies, also tend greatly to disturb the effects of elective attraction. These causes render it difficult to point out an example of simple elective attraction, which may in strictness be reckoned as such.

Double elective attraction takes place when two bodies, each consisting of two principles, are presented to each other, and mutually exchange a principle of each; by which means two new bodies, or compounds, are produced, of a different nature from the original compounds.

Under the same limitations as were pointed out in speaking of simple elective attraction, we may offer instances of double elective attraction. Let oxide of mercury be dissolved to saturation in the nitric acid, the water will then contain nitrate of mercury. Again, let potash be dissolved to saturation in the sulphuric acid, and the result will be a solution of sulphate of potash. If mercury were added to the latter solution, it would indeed tend to unite with the acid, but would produce no decomposition; because the elective attraction of the acid to the alkali is the strongest. So likewise, if the nitric acid alone be added to it, its tendency to unite with the alkali, strong as it is, will not effect any change, because the alkali is already in combination with a stronger acid. But if the nitrate of mercury be added to the solution of sulphate of potash, a change of principles will take place, the sulphuric acid will quit the alkali, and unite with the mercury, while the nitric acid combines with the alkali; and these two new salts, namely, nitrate of potash, and sulphate of mercury, may be obtained separately by crystallization.

The most remarkable circumstance in this process is, that the joint effects of the attractions of the sulphuric acid to mercury, and the nitric acid to alkali, prove to be stronger than the sum of the attractions between the sulphuric acid and the alkali, and between the nitrous acid and the mercury; for, if the sum of these two last had not been weaker, the original combinations would not have been broken.†

Mr. Kirwan, who first, in the year 1782, considered this subject with that attention it deserves, called the affinities which tend to preserve the original combinations, the quiescent affinities. He distinguished the affinities or attractions, which tend to produce a change of principles, by the name of the divellent affinities.

Some eminent chemists are disposed to consider as effects of double affinities, those changes of principles only, which would not have taken place without the assistance of a fourth principle. Thus, the mutual decomposition of sulphate of soda and nitrate of potash, in which the alkalis are changed, and sulphate of potash and nitrate of soda are produced, is not considered by them as an instance of double decomposition; because the nitre would have been decomposed by simple elective attraction, upon the addition of the acid only.

There are various circumstances which modify the effects of elective attraction, and have from time to time misled chemists in their deductions. The chief of these is the temperature, which, acting differently upon the several parts of compounded bodies, seldom fails to alter, and frequently reverses the effects of the affinities. Thus, if alcohol be added to a solution of nitrate of potash, it unites with the water, and precipitates the salt at a common temperature. But if the temperature be raised, the alcohol rises on account of its volatility, and the salt is again dissolved. Thus again, if sulphuric acid be added, in a common temperature, to a combination of phosphoric acid and lime, it will decompose the salt, and disengage the phosphoric acid; but if this same mixture of these principles be exposed to a considerable heat, the sulphuric acid will have its attraction to the lime so much diminished, that it will rise, and give place again to the phosphoric, which will combine with the lime. Again, mercury kept in a degree of heat very nearly equal to volatilizing it will absorb oxygen, and become converted into the red oxide formerly called precipitate *per se*; but if the heat be augmented still more, the oxygen will assume the elastic state, and fly off, leaving the mercury in its original state. Numberless instances of the like nature continually present themselves to the observation of chemists, which are sufficient to establish the conclusion, that the elective attractions are not constant but at one and the same temperature.

Many philosophers are of opinion, that the variations produced by change of temperature arise from the elective attraction of the matter of heat itself. But there are no decisive experiments either in confirmation or refutation of this hypothesis.

If we except the operation of heat,

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† The influence of insolubility and of gravity is here too much overlooked. It is a general law, that when compounds are mixed, new combinations will take place between those substances, which, when united, are most insoluble. The mercury is of itself perfectly insoluble, and it is many times heavier than potash or nitric acid. The sulphuric acid is much heavier than the nitric, and forms with mercury an insoluble salt. Hence the superior affinity of the nitric acid and potash to water, as well as gravitation, tends to precipitate the sulphate of mercury.

which really produces a change in the elective attractions, we shall find, that most of the other difficulties attending this subject arise from the imperfect state of chemical science. If to a compound of two principles a third be added, the effect of this must necessarily be different according to its quantity, and likewise according to the state of saturation of the two principles of the compounded body. If the third principle which is added be in excess, it may dissolve and suspend the compound which may be newly formed, and likewise that which might have been precipitated. The metallic solutions, decomposed by the addition of an alkali, afford no precipitate in various cases when the alkali is in excess; because this excess dissolves the precipitate, which would else have fallen down. If, on the other hand, one of the two principles of the compound body be in excess, the addition of a third substance may combine with that excess, and leave a neutral substance, exhibiting very different properties from the former. Thus, if cream of tartar, which is a salt of difficult solubility, consisting of potash united to an excess of the acid of tartar, be dissolved in water, and chalk be added, the excess unites with part of the lime of the chalk, and forms a scarcely soluble salt; and the neutral compound, which remains after the privation of this excess of acid, is a very soluble salt, greatly differing in taste and properties from the cream of tartar. The metals and the acids likewise afford various phenomena, according to their degree of oxidation. A determinate oxidation is in general necessary for the solution of metals in acids; and the acids themselves act very differently, accordingly as they are more or less acidified. Thus, the nitrous acid gives place to acids which are weaker than the nitric acid: the sulphurous acid gives place to acids greatly inferior in attractive power or affinity to the sulphuric acid. The deception arising from effects of this nature is in a great measure produced by the want of discrimination on the part of chemical philosophers; it being evident, that the properties of any compound substance depend as much upon the proportion of its ingredients, as upon their respective nature.

The presence and quantity of water is probably of more consequence than is yet supposed. Thus, bismuth is dissolved in nitrous acid, but falls when the water is much in quantity. The same is true of antimony. Ribaucout has shown the last (Annales de Chimie, xv. 122.) in alum, and it is likely that the fact is more common than is suspected. Whether the attraction and strength, as to quantity in saturation, be not variable by the presence or absence of water, must be referred to experiment.

The power of double elective attractions too, is disturbed by this circumstance. If muriate of lime be added to a solution of carbonate of soda, they are both decomposed, and the results are muriate of soda and carbonate of lime. But if lime and muriate of soda be mixed with just water sufficient to make them into a paste, and this be exposed to the action of carbonic acid gas, a saline efflorescence consisting of carbonate of soda will be formed on the surface, and the bottom of the vessel will be occupied by muriate of lime in a state of deliquescence.

M. Berthollet made a great number of experiments, from which he deduced the following law:—that in elective attractions the power exerted is not in the ratio of the affinity simply, but in a ratio compounded of the force of affinity and the quantity of the agent; so that quantity may compensate for weaker affinity. Thus an acid which has a weaker affinity than another for a given base, if it be employed in a certain quantity, is capable of taking part of that base from the acid which has a stronger affinity for it; so that the base will be divided between them in the compound ratio of their affinity and quantity. This division of one substance between two others, for which it has different affinities, always takes place, according to him, when three such are present under circumstances in which they can mutually act on each other. And hence it is, that the force of affinity acts most powerfully, when two substances first come into contact, and continues to decrease in power as either approaches the point of saturation. For the same reason it is so difficult to separate the last portions of any substance adhering to another. Hence, if the doctrine laid down by M. Berthollet be true, to its utmost extent, it must be impossible ever to free a compound completely from any one of its constituent parts by the agency of elective attraction; so that all our best established analyses are more or less inaccurate.

The solubility or insolubility of principles, at the temperature of any experiment, has likewise tended to mislead chemists, who have deduced consequences from the first effects of their experiments. It is evident, that many separations may ensue without precipitation; because this circumstance does not take place unless the separated principle be insoluble, or nearly so. The soda cannot be precipitated from a solution of sulphate of soda, by the addition of potash, because of its great solubility; but, on the contrary, the new compound itself, or sulphate of potash, which is much less soluble, may fall down, if there be not enough water present to suspend it. No certain knowledge can therefore be derived from the appearance or the want of precipitation, unless the products be carefully examined. In some instances all the products remain suspended, and in others they all fall down, as may be instanced in the decomposition of sulphate of iron by lime. Here the acid unites with the lime, and forms sulphate of lime, which is scarcely at all soluble; and the still less soluble oxide of iron, which was disengaged, falls down along with it.

Many instances present themselves, in which decomposition does not take place, but a sort of equilibrium of affinity is perceived. Thus, soda, added to the supertartrate of potash, forms a triple salt by combining with its excess of acid. So likewise ammonia combines with a portion of the acid of muriate of mercury, and forms the triple compound formerly distinguished by the barbarous name of sal alembroth.

When we reflect maturely upon all the circumstances enumerated, or slightly touched upon, in the foregoing pages, we may form some idea of the extensive field of research, which yet remains to be explored by chemists. If it were possible to procure simple substances, and combine two together, and to this combination of two to add one more of the other simple substances, the result of the experiment would in many cases determine, by the exclusion of one of the three, that its affinity to either of the remaining two was less than that between those two respectively. In this way it would be ascertained, in the progress of experimental inquiry, that the simple attractions of a series of substances were gradually increasing or diminishing in strength. Thus, ammonia separates alumina from the sulphuric acid; magnesia, in like manner, separates the ammonia; lime predominates, in the strength of affinity, over magnesia, as appears by its separating this last earth; the soda separates the lime, and itself gives place to the potash; and, lastly, potash yields its acid to barytes. The simple elective attractions of these several substances to sulphuric acid, are therefore in the inverted order of their effects: barytes is the strongest; and this is succeeded regularly by potash, soda, lime, magnesia, ammonia, and alumina. It is evident, that results of this nature, being tabulated, as was first done by the celebrated Geoffroy, and afterwards by Bergmann, must afford a valuable mass of chemical knowledge. It must be remarked, however, that these results merely indicate, that the powers are greater or less than each other; but how much greater or less is not determined, either absolutely or relatively. Tables of this nature cannot therefore inform us of the effects which may take place in the way of double affinity, for want of the numerical relations between the attracting powers. Thus, when we are in possession of the order of the simple elective attractions between the sulphuric acid and a series of substances, and also between the nitrous acid and the same substances; and when, in addition to this, the respective powers of each of the acids upon every one of the substances singly taken, are known, so far as to determine which will displace the other; yet we cannot thence foretell the result of applying two combinations to each other, each containing an acid united with one of the number of simple substances. Or, more concisely, a table of simple elective attractions can be of no use to determine the effects of double elective attraction, unless the absolute power of the attractions be expressed by number instead of their order merely.

* It has been often remarked, that the action of a substance is diminished in proportion as it approaches to a state of saturation; and this diminution of power has been employed to explain several chemical phenomena. It is likewise known, that the resistance found in expelling a substance from the last portions of a combination, either by affinity or heat, is much greater than at the commencement of the decomposition, and sometimes such, that its entire decomposition cannot be effected. Thus the black oxide of manganese exposed to heat will part with only a certain definite quantity of its oxygen. No degree of heat can expel the whole.

According to Berthollet, when two substances are in competition to combine with a third, each of them obtains a degree of saturation proportionate to its affinity multiplied by its quantity, a product, which he denominates *mass*. The subject of the combination divides its action in proportion to the masses, and by varying the latter, this illustrious chemist thinks, that the results also will be varied. The following are the forces which he regards as exercising a great influence upon chemical combinations and phenomena, by concurring with or opposing the mutual affinity of the substances brought into action. 1. The action of solvents, or the affinity which they exert according to their proportion. Thus, if into a very dilute solution of muriate of lime, a solution of sulphate of soda be poured, no precipitate of sulphate of lime will happen, though the quantity of the solvent water be less than is necessary to dissolve the calcareous sulphate. If the same two saline solutions be mixed with less water, the sulphate of lime will fall in a few seconds, or a few minutes, according to the strength of the mingled solutions. 2. The force of cohesion, which is the effect of the mutual affinity of the particles of a substance or combination. Hence we can easily see why a solution of pure potash, which so readily dissolves pulverulent alumina, has no effect on alumina concreted and condensed in the oriental gems. The lowest red heat kindles charcoal, or determines its combination with atmospherical oxygen; but a much higher temperature is requisite to burn the same carbonaceous matter, more densely aggregated in the diamond. 3. Elasticity, whether natural or produced by heat; which has, by some, been considered as the affinity of caloric. (†1) Of the influence of this power a fine illustration is afforded by muriate of lime and carbonate of ammonia. When a solution of the latter salt is poured into one of the former, a double decomposition instantly takes place: carbonate of lime falls to the bottom in powder, and muriate of ammonia floats above. Let this liquid mixture be boiled for some time; exhalation of ammoniacal gas will be perceived by the nostrils, and the carbonate of lime will be redissolved; as may be proved by the further addition of carbonate of ammonia. (†2) This will cause an earthy precipitate from the liquid, which prior to ebullition was merely muriate of ammonia. 4. Efflorescence, a power which acts only under very rare circumstances. It is exemplified in the natron lakes of Egypt; on the margin of which, according to Berthollet, carbonate of lime decomposes muriate of soda, in consequence of the efflorescing property of the resulting carbonate. 5. Gravity likewise exerts its influence, particularly when it produces the compression of elastic fluids; but it may always without inconvenience be confounded with the force of cohesion.

M. Berthollet thinks, that as the tables of affinity have all been constructed upon the supposition, that substances possess different degrees of affinity, which produce the decompositions and combinations that are formed, independently of the proportions and other conditions which contribute to the results; these tables are calculated only to give a false idea of the degrees of chemical action of the substances arranged in them. "The denomination of *elective* affinity," says he, "is in itself erroneous, since it supposes the union of one entire substance with another, in preference to a third, while there is only a division of action, subject to other chemical conditions." The force of cohesion, which was formerly considered merely as an obstacle to solution, limits not only the quantities of substances which may be brought into action in a liquid, and consequently modifies the conditions of the saturation which follows; but it is the power which causes the precipitations and crystallizations that take place, and determines the proportions of such combinations as are made by quitting the liquid; it is this force which sometimes even produces the separation of a substance, without its forming any combination with another substance, as has been remarked in metallic precipitations. Elasticity acts by producing effects opposite to those of cohesion, and which consists either in withdrawing some substances from the action of others in a liquid, or in diminishing the proportion which exists within the sphere of activity; but when all the substances are in the elastic state, their action is subjected to the same conditions. If tables were formed which would represent the disposition to insolubility or volatility, in the different combinations, they would serve to explain a great number of combinations which take their origin from the mixture of different substances, and from the influence of heat. These considerations need not prevent us, says Berthollet, from using the term affinity to denote the whole chemical power of a body exerted in a given situation, even by its present constitution, its proportion, or even by the concurrence of other affinities; but we must avoid considering this power as a constant force, which produces compositions and decompositions. All substances, according to him, exert a mutual action during the time they are in the liquid state; so that in a solution, for example, of sulphate of potash and muriate of soda, these two salts are not distinct, while there is no cause to determine the separation from their combination; but there exists in this liquid, sulphuric acid, muriatic acid, soda, and potash. In like manner, when the proper quantity of carbonate of potash is added to muriate of soda, the mingled solution does not consist of carbonate of soda and muriate of potash, resulting from complex affinity, but contains simply muriatic and carbonic

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(†1) This is obscure. Elasticity, as an antagonist of chemical affinity, seems always to result from calorific repulsion. Particles evidently arrange themselves of choice in certain angles, from which they may be made to deviate, to a certain extent, in obedience to exterior force; and yet they regain their figure, as soon as unconstrained. Perhaps this is what the author means by natural elasticity. For "*affinity of caloric*" we ought probably to read *effects of caloric*.

(†2) It is not the carbonate of lime, but the lime of the carbonate, that is redissolved. I question if the "exhalation" be not carbonate of ammonia, instead of ammoniacal gas.

acids with potash and soda, in quadruple union and saturation. It is the crystallizing property of the soda carbonate, which, after due evaporation, determines the definite decomposition, and not any power of elective attraction. Or generally, when one substance separates from a combination by the introduction of another, it is not merely from being supplanted by the superior affinity of an antagonist, but because its intrinsic tendency to the solid or gaseous form educes it from its former associate. There is certainly much truth in the proposition of Berthollet.

But with regard to the indefinite partition of a base between two rival acids, and of an acid between two rival bases, a doctrine which that profound philosopher laboured to establish by a wide experimental induction, many facts of an irreconcileable nature occur. Sir H. Davy has remarked with his usual good judgment, that were this proposition correct, it is evident that there could be scarcely any definite proportions; a salt crystallizing in a strong alkaline solution would be strongly alkaline; in a weak one less alkaline; while in an acid solution it would be acid. But this does not seem to be the case. In combinations of gaseous bodies, whose constitution gives their particles perfect freedom of motion, the proportions are definite and unchangeable, however we may change the proportions of the aeriform mixture. And in all solid compounds that have been accurately examined, in which there is no chance of mechanical mixture, the same law seems to prevail. Different bodies may indeed be dissolved in different menstrua in very various proportions, but the result may be regarded as a mixture of different solutions, rather than a combination. With regard to glasses and metallic alloys, adduced by Berthollet, it is sufficient to know that the points of fusion of alkali, glass, and oxides of lead and tin, are so near each other, that transparent *mixtures* of them may be formed. The attractive power of matter is undoubtedly general, but in the formation of aggregates, certain definite arrangements take place. Bergmann observed long ago, that when nitric acid was digested on sulphate of potash, a portion of nitre was formed, in apparent contradiction to the superior affinity which he had assigned to sulphuric acid for the potash. But he also gave what appears to be a satisfactory explanation of this seeming anomaly, which Berthollet has adduced in support of his views of indefinite and universal partition.

Sulphuric acid tends to combine in two distinct but definite proportions with potash, forming the neutral sulphate and the bisulphate. Nitric acid may therefore abstract from the neutral salt, that portion of potash which it should lose to pass into the acidulous salt; but it will not deprive it of any more. Hence this very example is decidedly adverse to the indefinite combinations and successive partitions taught by Berthollet. The above decomposition resolves itself evidently, therefore, into a case of double affinity. That a large quantity of pure potash can separate a little sulphuric acid from the sulphate of barytes, has been stated by Berthollet; but it is a circumstance difficult to demonstrate. If the operation be conducted with access of air, then carbonate of potash is readily formed, and a well known double affinity comes into play, viz. that of barytes for carbonic acid on one hand, and of sulphuric acid for potash on the other. Supposing the agency of carbonic acid to be excluded, then are we to believe that the potash having become a soluble sulphate, exists in liquid union with pure barytes? See M. Dulong's experiments further on.

When M. Berthollet separated a little potash from sulphuric acid by soda, he merely formed a little bisulphate of potash, while the free potash united to the water and alcohol, for which it has a strong affinity, and sulphate of soda was also formed. This, therefore, is a very intelligible case of compound attraction. According to M. Berthollet, whenever an earth is precipitated from a saline combination, by an alkali, it should carry down with it a portion of its acid associate. But sulphate of magnesia acted on by potash, yields an earthy precipitate, which, after proper washing, betrays the presence of no retained sulphuric acid. The neutral salts of soda and potash part with none of their acid to magnesia, by the longest digestion in their solutions. If on the tartrate of lime, or oxalate of lead, the portion of sulphuric acid adequate to saturate these respective bases be poured, entire decomposition will be effected without any partition whatever. Now, sulphate of lime, which is the result in the first case, being actually a much more soluble salt than the tartrate, we should expect a portion of the latter to resist decomposition by the aid of its cohesive force. A plate of iron plunged into a solution of sulphate of copper, separates the whole of the latter metal. An equally absolute decomposition is effected by zinc on the saline solutions of lead and tin. The sum total of oxygen and acid is here transferred to the decomposing body, without any partition whatever.

We have already observed, that sulphate of barytes digested in a hot solution of carbonate of potash, gives birth to a portion of carbonate of barytes and sulphate of potash. But by M. Dulong's experiment, the reverse decomposition is possible, viz. carbonate of barytes being digested in solution of sulphate of potash, we obtain sulphate of barytes and carbonate of potash. Are we hence to infer, that sulphate of barytes and carbonate of potash having for some time amused the operator by the production of an alkaline sulphate and earthy carbonate, will change their mood, and retracing their steps, restore things to their pristine condition; and thus in alternate oscillation for ever?

If chlorine gas be made to act on the oxides of mercury, tin, or antimony, it will unite to the metallic base, and displace every particle of the oxygen. Now, the resulting chlorides cannot owe their purity to any superiority of cohesive force which they possess over the oxides, which, on the contrary, are both denser and more fixed than the new compounds. Finally, if 25 parts of pure magnesia mixed with 35.6 of dry lime, be digested in 85 parts of nitric acid, sp. gr. 1.500, diluted with water, we shall find that the whole lime will be dissolved, but not a particle of the magnesia. On decanting the neutral calcareous nitrate, washing and drying the earthy residuum, we shall procure the 25 parts of magnesia unchanged.

We are, therefore, entitled to affirm, that affinity is elective, acting in the different chemical bodies with gradations of attractive force, liable however to be modified, as we have shown in the case of muriate of lime and carbonate of ammonia, by temperature, and other adventitious powers.

Decompositions which cannot be produced by single attractions, may be effected by double affinity; and that, we may expect with the greater certainty, *a priori*, if one of the two resulting compounds of the double interchange, naturally exists in the solid or aeriform state. And if the one resulting compound be solid and the other gaseous, then decomposition will be certain and complete. This applies with equal force to single affinities, or decompositions. Thus when sulphuric acid and muriate of lime in due proportions are exposed to heat, a perfect decomposition is accomplished, and pure sulphate of lime and muriatic acid gas are produced. But when the various mixed ingredients remain *in solution*, it is then reasonable to think with Berthollet, that a reciprocal attraction pervades the whole, modifying its nature and properties. Thus solution of sulphate of copper is blue, that of muriate of copper is green. Now, if into a solution of the former salt, we pour muriatic acid, we shall observe this robbing the sulphuric acid of a quantity of the cupreous oxide, proportional to its mass; for the more muriatic acid we add, the greener will the liquid become. But if, by concentration, the sulphate of copper be suffered to crystallize, the phenomena change; a new force, that of crystallization, is superadded, which aids the affinity of the sulphuric acid, and decides the decomposition. The surplus of each of these acids is employed in counterbalancing the surplus of its antagonist, and need not be considered as combined with the copper. Here, however, we verge on the obscure and unproductive domain of chemical metaphysics, a region in which a late respectable systematist delighted to expatiate.

M. Bethollet estimates the attractive forces or affinities of bodies of the same class, to be *inversely* as their saturating quantities. Thus, among acids, 50 parts of real sulphuric, will saturate as much potash or soda as 67½ of real nitric, and as 27½ of carbonic. Thus too, 21¼ of ammonia will saturate as much acid as 25 of magnesia, 35½ of lime, and 59½ of potash. Hence he infers that the carbonic acid is endowed with a higher affinity than the sulphuric; and this, than the nitric. The same proposition applies to ammonia, magnesia, lime and potash. But in direct hostility to this doctrine, we have seen lime exercise a greater affinity for the acids than magnesia. And though M. Berthollet has ingeniously sought to explain away the difficulty about potash, ammonia, and carbonic acid, by referring to the solid or gaseous results of their action; yet it is hard to conceive of solidity operating in producing an effect, before solidity exists, and of elasticity operating while the substance is solid or liquid. On this point a good syllogism has been offered by Sir H. Davy. "The action," says this profound chemist, "between the constituents of a compound must be mutual. Sulphuric acid, there is every reason to believe, has as much attraction for barytes, as barytes has for sulphuric acid, and barytes is the alkaline substance of which the largest quantity is required to saturate sulphuric acid; therefore, on M. Berthollet's view, it has the weakest affinity for that acid; but less sulphuric acid saturates this substance than any other earthy or alkaline body. Therefore, according to M. Berthollet, sulphuric acid has a stronger affinity for barytes than for any other substance; which is contradictory."

In the table of chemical equivalents at the end of the Dictionary, will be found a view of the definite proportions in which the various chemical bodies combine, referred to their primary or lowest numerical terms, vulgarly called the *weights* of the *atoms*.

Mr. Higgins, the real author of the Atomic Theory, in first promulgating its principles in his Comparative View of the

Phlogistic and Antiphlogistic Hypotheses, connected their exposition with general views of the relative forces of affinity among the combining particles. These forces he illustrates by diagrams, to which I have adverted, in the article EQUIVALENTS (CHEMICAL). This joint consideration of combining *force* and combining *ratio*, has been neglected by subsequent writers; whence, Mr. Higgins says, "The atomic doctrine has been applied by me in abtruse and difficult researches. Its application by Mr. Dalton, has been in a general and popular way; and it is from these circumstances alone, that it gained the name of Dalton's Theory."

Since the chemical statics appeared, perhaps no chemist has contributed so many important facts to the doctrines of affinity as M. Dulong. His admirable inquiries concerning the mutual decomposition of soluble and insoluble salts, were presented to the National Institute, and afterwards published in the Annales de Chimie, tom. 82; from which they were translated into the 35th and 36th volumes of Nicholson's Journal, and an abstract of them was given in the 41st vol. of the Phil. Mag. Notwithstanding such means of notoriety, it is amusing to observe so unwearied a compiler as Dr. Thomson, recently appropriating to his friend Mr. Phillips, the discovery of a fact observed and recorded years before by M. Dulong; and treating as an anomaly, what the French philosopher had shown to be none, but had referred with equal sagacity and industry to general principles.

After the labours of Bergmann and Berthollet, chemistry seemed to leave little further to be desired, relative to the mutual decomposition of soluble salts. But the insoluble salts are likewise susceptible of exchanging their principles with a great number of the soluble salts. "This class of phenomena," says M. Dulong, "though almost as numerous as that which embraces the soluble salts, and capable of affording new resources to analysis, has not yet been examined in a general manner."

The action of the soluble carbonates on the insoluble salts, is the only one which had been at all studied. Thus carbonates of potash and soda in solution, had been employed conveniently to decompose sulphate of barytes. M. Dulong had an opportunity in some particular researches, to observe a considerably extensive number of facts, relating to the mutual decomposition of the soluble and insoluble salts, and endeavoured, he says, to determine the general cause of these phenomena, and the method of foreseeing their results, without being obliged to retain by an effort of memory, of which few persons would be capable, all the direct observations which would be requisite to ascertain them.

M. Dulong found by experiment, that all the insoluble salts are decomposable by the carbonate of potash or the carbonate of soda, and in some instances with curious phenomena. When sulphate of barytes, phosphate of barytes, or oxalate of lime, is boiled with solution of bicarbonate, or carbonate of potash, a considerable part of the insoluble sulphate is constantly transformed into a carbonate of the same base; but on reaching a certain limit, the decomposition stopped, although there remained sometimes a very considerable quantity of the soluble carbonate not decomposed. M. Dulong convinced himself, that the different degrees of concentration of the alkaline solution, produced but very slight variations in the results of this decomposition. He took 10 grammes of dry subcarbonate of potash, and 7.66, being their equivalent proportion, of dry subcarbonate of soda; quantities containing each 3.07 grammes of carbonic acid. They were separately dissolved in 250 grammes of water, and each solution was kept in ebullition for two hours, on 8 grammes of the sulphate of barytes. On analyzing the two residues, it was found that the potash experiment yielded 2.185 grammes, and the soda only 1.833; or in the proportion of 6 to 5. Is this difference to be ascribed to the difference in the attractive forces of the two alkalis; to the more sparing solubility, or greater attractive force of the sulphate of potash; or to both causes conjointly?

Since the alkaline carbonates lose their decomposing agency when a certain proportion of the alkaline sulphate is formed, M. Dulong tried to ascertain the limits by the following experiment: 7 grammes of sulphate of potash, with 6 of subcarbonate, dissolved in 250 of water, were boiled with the sulphate of barytes for several hours, without the least trace of decomposition being evinced. The supernatant liquid, filtered, and boiled on carbonate of barytes, produced a considerable quantity of sulphate; but ceased acting before this sulphate of potash was exhausted. The same phenomena were obtained with carbonate and sulphate of soda. "Lastly, the sulphate of potash and the sulphate of soda alone, and perfectly neutral, re-acted likewise upon the carbonate of barytes, and produced on one part, sulphate of barytes, but on the other the subcarbonate of potash or soda which remained in solution, together with the portion of the sulphate which resisted the decomposition. 20 grammes of crystallized sulphate of soda, and 10 grammes of sulphate of potash, were separately dissolved in 260 of water. Each solution was boiled for 2 hours on 20 grains of carbonate of barytes. The sulphate of soda produced 10.17 gr. of sulphate of barytes, and the sulphate of potash 9.87." Had 108 of sulphate of potash been employed, which is the true equivalent of 200 sulphate of soda in crystals, a somewhat larger product would have been obtained than 9.87. This experiment, however, is most satisfactory with regard to the amount of decomposition. The mutual action of the insoluble carbonates, with the soluble salts, whose acids form, with the bases of these carbonates, insoluble salts, is equally general with that of the soluble carbonates on the insoluble salts. The following is M. Dulong's table of results:

Carbonate of Barytes.	Carbonate of Strontian.	Carbonate of Lime.	Carbonate of Lead.
Sulphate of Potash	Id.	0	Id.
———— Soda	Id.	0	Id.
———— Lime	Id.	0	Id.
———— Ammonia	Id.	Id.	Id.
———— Magnesia	Id.	...	Id.
Phosphate of Soda	Id.	Id.	Id.
———— Ammonia	Id.	Id.	Id.
Sulphite of Potash	Id.	Id.	Id.
Phosphite of Potash	Id.	Id.	Id.
———— Soda	Id.	Id.	Id.
———— Ammonia	Id.	Id.	Id.
Borate of Soda	Id.	...	Id.
Arseniate of Potash	Id.	Id.	Id.
———— Soda	Id.	Id.	Id.
Oxalate of Potash	Id.	Id.	Id.
———— Ammonia	Id.	Id.	Id.
Fluate of Soda	Id.	Id.	Id.
Chromate of Potash	Id.	Id	Id.

All those salts which have ammonia for their base, are completely decomposed by the insoluble carbonates found in the same column. The new insoluble salt replaces the carbonate which is decomposed, and the carbonate of ammonia flies off. Hence, if a sufficient quantity of insoluble carbonate be present, the liquid will become pure water.

When the soluble salt has an insoluble base, the decomposition does not meet with any obstacle, but continues until the liquid becomes mere water. Thus, solution of sulphate of magnesia, boiled with carbonate of barytes, will be resolved into an insoluble carbonate and sulphate, provided enough of carbonate of barytes be present. Otherwise a portion of the magnesian carbonate being dissolved in its own sulphate, gives alkaline properties to the solution.

If the base be metallic, it almost always forms a salt with excess of oxide, which being insoluble, precipitates.

The general inferences of M. Dulong's inquiries are the following: 1. That all the insoluble salts are decomposed by the subcarbonates of potash or soda, but that a mutual exchange of the principles of these salts cannot in any case be completely made; or in other words, that the decomposition of the subcarbonates is only partial. 2. That all the soluble salts, of which the acid forms, with the base of the insoluble carbonates, an insoluble salt, are decomposed by these carbonates, until the decomposition has reached a certain limit which it cannot pass.

When a soluble subcarbonate acts on an insoluble salt, in proportion as the carbonic acid is precipitated on the base of the insoluble salt, it is replaced in the solution by a quantity of another acid, capable of *completely* neutralizing the alkali. Thus, during the whole course of the decomposition, fresh quantities of *neutral* salt replace the corresponding quantities of an imperfectly saturated alkaline compound; and if we view the excess of alkaline power in the undecomposed subcarbonate, or its unbalanced capacity of saturation, as acting upon both acids, it is evident that in proportion as the decomposition advances, the liquid *approaches* more and more to the neutral state. In the inverse experiment, a contrary change supervenes. Each portion of the acid of the soluble salt, (sulphate of soda for example), which is precipitated on the base of the insoluble carbonate, is replaced by a quantity of carbonic acid, which forms with the corresponding base, an alkaline subcarbonate; and the more of the first acid is precipitated upon the earthy base, the more subcarbonate the liquid contains, and the further does its state *recede* from neutralization. This consideration seems to lead directly to the following theory of these decompositions.

It is known, says M. Dulong, that all the salts, even those which possess the greatest cohesion, yield to caustic potash or soda, a more or less considerable portion of their acid, according to circumstances. Now the alkaline subcarbonates may be considered as weak alkalis, which may take from all the insoluble salts a small quantity of their acids. This effect would soon be limited if the alkali were pure, in consequence of the resistance offered by the pure and soluble base. But the latter meeting in the liquid, an acid with which it can form an insoluble salt, unites with it, and thus re-establishes the primitive conditions of the experiment. The same effects are produced successively on new portions of the bodies, till the degree of saturation of the liquid is in equilibrium with the cohesive force of the insoluble salt, so that the feebler this resistance may be, the more progress the decomposition will make. And again, when an insoluble carbonate is in contact with a neutral soluble salt, the base of the carbonate will tend to take part of the acid of the neutral salt; and if, from this union, an insoluble salt can result, the force of cohesion peculiar to this compound, will determine the formation. The carbonic acid, released from the attraction of the earthy base by the fixed acid, instantly attaches itself to the surrounding alkali, forming a subcarbonate which replaces the decomposed neutral salt. The precipitation of the fixed acid on the insoluble carbonate, and the absorption of carbonic acid by the liquid continues, until the alkalinity thereby developed, becomes so strong as to resist the precipitation of the acid; thus forming a counterpoise to the force by which that precipitation was accomplished. All action then ceases, so that the more cohesion the insoluble salt possesses, the greater will be the proportion of acid taken from the soluble salt.

When the carbonate of potash can no longer decompose the sulphate of barytes, the carbonic acid which remains in the solution, is to the sulphuric acid nearly in the ratio of 3 to 1; and when the sulphate of potash can no longer act upon the carbonate of barytes, these two acids are nearly in the ratio of 3 to 2; whence it follows, that the first liquor is much more alkaline than the second.

It is easy to account for this difference by examining the conditions of the equilibrium established in the two cases. When the sulphate of potash no longer decomposes the carbonate of barytes, it is because the excess of alkali, developed in the liquid, forms a counterpoise to the power with which sulphate of barytes tends to be produced in these circumstances. And when the subcarbonate of potash can no longer decompose the sulphate of barytes, it is because there is not such an excess of alkali in the liquid, as is capable of overcoming the cohesion and attraction between the elements of that salt. Now we know, that it requires a greater force to overcome an existing attractive power, than to maintain the quiescent condition. Therefore the subcarbonate of potash ought to cease to decompose the sulphate of barytes, before the sulphuric and carbonic acids are in the same relation in which they are found, when the equilibrium is established by the inverse experiment. Hence we see, that a mixture of sulphate and subcarbonate of potash, in which the proportions of their two acids shall be within the limits pointed out, will have no action either on the sulphate or carbonate of barytes. For the other insoluble salts, there will be other relations of quantity; but there is always a certain interval, more or less considerable, between their limits. The mutual action of sulphate of soda and carbonate of barytes is almost instantaneous. It is sufficient to pour a boiling hot solution of the sulphate, on the carbonate placed on a filter, in order that more than three-fourths of the sulphuric acid be precipitated, and replaced by a corresponding quantity of carbonic acid.

In the first part of the Philosophical Transactions for 1809, we have tables of elective attractions by Dr. Thomas Young, a philosopher of the very first rank, whom the late ingenious Dr. Wells pronounced the most learned man in England. These have been unaccountably overlooked by our different systematic writers, though they are, both in accuracy and ingenuity, far superior to the tables which, with unvarying routine of typography, are copied into their compilations, I conceive it will be doing an essential service to chemical students, to lay before them the tables of Dr. Young, accompanied with his admirable remarks on the sequences of double decompositions.

Attempts have been made, by several chemists, to obtain a series of numbers, capable of representing the mutual attractive forces of the component parts of different salts; but these attempts have hitherto been confined within narrow limits, and have indeed been so hastily abandoned, that some very important consequences, which necessarily follow from the general principle of a numerical representation, seem to have been entirely overlooked. It appears that nearly all the phenomena of the mutual actions of a hundred different salts may be correctly represented by a hundred numbers, while, in the usual manner of relating every case as a different experiment, above two thousand separate articles would be required.

Having been engaged in the collection of a few of the principal facts relating to chemistry and pharmacy, Dr. Young was induced to attempt the investigation of a series of these numbers; and he has succeeded in obtaining such as appear to agree sufficiently well with all the cases of double decompositions which are fully established, the exceptions not exceeding twenty, out of about twelve hundred cases enumerated by Fourcroy. The same numbers agree in general with the order of simple elective attractions, as usually laid down by chemical authors; but it was of so much less importance to accommodate them to these, that he has not been very solicitous to avoid a few inconsistencies in this respect; especially as many of the bases of the calculation remain uncertain, and as the common tables of simple elective attractions are certainly imperfect, if they are considered as indicating the order of the independent attractive forces of the substances concerned. Although it cannot be expected that these numbers should be accurate measures of the forces which they represent, yet they may be supposed to be tolerable approximations to such measures; at least, if any two of them are nearly in the true proportion, it is probable that the rest cannot deviate very far from it: thus, if the attractive force of the phosphoric acid for potash is about eight-tenths of that of the sulphuric acid for barytes, that of the phosphoric acid for barytes must be about nine-tenths as great. But they are calculated only to agree with a certain number of phenomena, and will probably require many alterations, as well as additions, when all other similar phenomena shall have been accurately investigated.

"There must be a sequence," says Dr. Young, "in the simple elective attractions. For example, there must be an error in the common tables of elective attractions, in which magnesia stands above ammonia under the sulphuric acid, and below it under the phosphoric; and the phosphoric acid stands above the sulphuric under magnesia, and below it under ammonia; since such an arrangement implies that the order of the attractive forces is this: phosphate of magnesia, sulphate of magnesia, sulphate of ammonia, phosphate of ammonia, and again phosphate of magnesia; which forms a circle, and not a sequence. We must therefore either place magnesia above ammonia under the phosphoric acid, or the phosphoric acid below the sulphuric under magnesia; or we must abandon the principle of a numerical representation in this particular case.

"In the second place, there must be an agreement between the simple and double elective attractions. Thus, if the fluoric acid stands above the nitric under barita, and below it under lime, the fluate of barita cannot decompose the nitrate of lime, since the previous attractions of these two salts are respectively greater than the divellent attractions of the nitrate of barita and the fluate of lime. Probably, therefore, we ought to place the fluoric acid below the nitric under barita; and we may suppose, that when the fluoric acid has appeared to form a precipitate with the nitrate of barita, there has been some fallacy in the experiment.

"The third proposition is somewhat less obvious, but perhaps of greater utility: there must be a continued sequence in the order of double elective attractions; that is, between any two acids we may place the different bases in such an order, that any two salts, resulting from their union, shall always decompose each other, unless each acid be united to the base nearest to it; for example, sulphuric acid, barita, potash, soda, ammonia, strontia, magnesia, glucina, alumina, zirconia, lime, phosphoric acid. The sulphate of potash decomposes the phosphate of barita, because the difference of the attractions of barita for the sulphuric and phosphoric acids is greater than the difference of the similar attractions of potash; and in the same manner, the difference of the attractions of potash is greater than that of the attractions of soda; consequently the difference of the attractions of barita must be much greater than that of the attractions of soda, and the sulphate of soda must decompose the phosphate of barita; and in the same manner it may be shown, that each base must preserve its relations of priority or posteriority to every other in the series. It is also obvious, that, for similar reasons, the acids may be arranged in a continued sequence between the different bases; and when all the decompositions of a certain number of salts have been investigated, we may form two corresponding tables, one of the sequences of the bases with the acids. and another of those of the acids with the different bases; and if either or both of the tables are imperfect, their deficiencies may often be supplied, and their errors corrected. by a repeated comparison with each other."

In the table of simple elective attractions, he has retained the usual order of the different substances; inserting again in parentheses such of them as require to be transposed, in order to avoid inconsequences in the simple attractions: He has attached to each combination marked with an asterisk the number deduced from the double decompositions, as expressive of its attractive force; and where the number is inconsistent with the corrected order of the simple elective attractions, he has enclosed it in a parenthesis. Such an apparent inconsistency may perhaps in some cases be unavoidable, as it is possible that the different proportions of the masses concerned in the operations of simple and compound decomposition, may sometimes cause a real difference in the comparative magnitude of the attractive forces. Those numbers to which no asterisk is affixed, are merely inserted by interpolation, and they can only be so far employed for determining the mutual actions of the salts to which they belong, as the results which they indicate would follow from the comparison of any other numbers, intermediate to the nearest of those which are more correctly determined. He was not able to obtain a sufficient number of facts relating to the metallic salts, to enable him to comprehend many of them in the tables.

He thought it necessary to make some alterations in the orthography generally adopted by chemists, not from a want of deference to their individual authority, but because it appeared to him that there are certain rules of etymology, which no modern author has a right to set aside.

TABLES OF ELECTIVE ATTRACTIONS, By Dr. Young.

1. *TABLE of the Sequences of the Bases with the different Acids.*

In all mixtures of the aqueous solutions of two salts, each acid remains united to the base, which stands nearest to it in this Table.

SULPHURIC ACID.

Barita	Barita	Barita	Barita	Barita	Barita	Potash	Barita	Barita	Lead
Strontia	Strontia	Potash	Potash	Potash	Potash	Soda	Strontia	Potash	Mercury
Lime	Lime	Soda	Soda	Soda	Soda	Barita	Lime	Soda	Iron
(Silver?)	Potash	Ammonia	Strontia	Strontia	Strontia	Strontia	Potash	Ammonia	Potash
(Mercury?)	Soda	Strontia	Ammonia	Ammonia (4)	Ammonia (5)	Ammonia (6)	Soda	Strontia	Soda
Potash	(Mercury?)	Magnesia (3)	Magnesia	Magnesia (4)	Magnesia	Lime	Magnesia?	Magnesia	Magnesia
Soda	(Iron?)	Glycina	Glycina	Glycina	Lime	Magnesia	Ammonia	Glycina	
Zinc	Magnesia	Alumina	Alumina	Alumina	Glycina	Glycina	Glycina	Alumina	Lead
Iron	Ammonia (2)	Zirconia	Zirconia	Zirconia	Alumina	Alumina	Alumina	Zirconia	Zinc
Copper	Glycina	Lime	Lime	Lime	Zirconia	Zirconia	Zirconia	Lime?	Copper
Magnesia	Alumina (2)								
Ammonia (1)	Zirconia								
Glycina	(Copper?)								
Alumina									
Zirconia									
NITRIC	MURIATIC	PHOSPHORIC	FLUORIC	SULPHUROUS	BORACIC	CARBONIC	(NITROUS)	(PHOSPHOROUS)	(ACETIC)

(1.) Ammonia stands above magnesia when cold. (2.) A triple salt is formed. (3.) Perhaps magnesia ought to stand lower. (4.) A compound salt is formed, and when hot, magnesia stands above ammonia. (5.) Fourcroy says, that sulphate of strontia is decomposed by borate of ammonia. (6.) With heat, ammonia stands below lime and magnesia.

TABLE II. By Dr. Young.

NITRIC ACID.

NITRIC AND MURIATIC ACIDS.

Barita	Potash	Barita	Potash	Barita (10)	Potash
Potash	Soda	Potash	Soda	Potash	Soda
Soda	Ammonia	Soda	Ammonia	Soda	Barita (10)
Strontia	Magnesia	Ammonia	Magnesia	Ammonia	Ammonia (7,11)
Lime	Glycina	Magnesia	Glycina	Magnesia	Magnesia (7)
Magnesia (7)	Alumina	Glycina	Alumina	Glycina	Strontia
Ammonia (7)	Zirconia (8)	Alumina	Zirconia	Alumina	Lime
Glycina	Barita	Zirconia	Barita	Zirconia	Glycina
Alumina	Strontia	Strontia (9)	Strontia	Strontia	Alumina
Zirconia	Lime	Lime	Lime	Lime	Zirconia
Muriatic	Phosphoric	Fluoric	Sulphurous	Boracic	Carbonic.

(7.) A triple salt is formed. (8.) Fourcroy says, that the muriate of zirconia decomposes the phosphates of barita and strontia. (9.) According to Fourcroy's account, the fluate of strontia decomposes the muriates of ammonia, and of all the bases below it; but he says in another part of the same volume, that the fluate of strontia is an unknown salt. (10.) According to Fourcroy's account of these combinations, barita should stand immediately below ammonia in both of these columns. (11.) With heat, the carbonate of lime decomposes the muriate of ammonia.

PHOSPHORIC ACID.

Barita	Lime	Barita	Potash	Barita
Lime	Barita	Lime	Soda	Lime
Potash	Potash	Potash	Barita	Potash
Soda	Soda	Soda	Lime (13)	Soda
Strontia	Strontia	Strontia	Strontia	Strontia
Magnesia	Magnesia	Ammonia (12)	Ammonia	Magnesia
Ammonia	Ammonia	Magnesia	Magnesia	Glycina?
Glycina	Glycina	Glycina	Glycina	Alumina
Alumina	Alumina	Alumina	Alumina	Zirconia
Zirconia	Zirconia	Zirconia	Zirconia	
Fluoric	Sulphurous	Boracic	Carbonic	(Phosphorous)

(12.) According to Fourcroy, the phosphate of ammonia decomposes the borate of magnesia. (13.) Fourcroy says, that the carbonate of lime decomposes the phosphates of potash and of soda.

FLUORIC ACID.

Lime	Lime	Potash
Potash	Barita	Soda
Soda	Strontia	Lime
Magnesia	Potash	Barita
Ammonia	Soda	Strontia
Glycina	Ammonia	Ammonia (14)
Alumina	Magnesia	Magnesia
Zirconia	Glycina	Glycina
Strontia	Alumina	Alumina
Barita	Zirconia	Zirconia
Sulphurous	Boracic	Carbonic

(14.) According to Fourcroy, the carbonate of ammonia decomposes the fluates of arita and strontia.

DR. YOUNG'S SECOND TABLE—(CONCLUDED.)

SULPHUROUS ACID.			BORACIC ACID.	
Barita	Potash	Lime	Zirconia	Potash
Strontia	Soda	Strontia	Alumina	Soda
Potash	Barita (15.)	Barita	Glycina	Lime
Soda	Strontia	Zirconia	Ammonia	Barita
Ammonia	Ammonia	Alumina	Magnesia	Strontia
Magnesia	Lime	Glycina	Strontia	Magnesia
Lime	Magnesia	Magnesia	Soda	Ammonia
Glycina	Glycina	Ammonia	Potash	Glycina
Alumina	Alumina	Soda	Barita	Alumina
Zirconia	Zirconia	Potash	Lime	Zirconia
BORACIC	CARBONIC	(NITROUS)	(PHOSPHOROUS ?)	CARBONIC

(15.) Fourcroy says, that the sulphite of barita decomposes the carbonate of ammonia.

III. *A Table of the Sequences of the Acids with different Bases, by* Dr. YOUNG.

	BARITA.			STRONTIA.					LIME.				POTASH SODA	MAG-NESIA.	
Sulphuric	S	C	S	S	C	S	P	S	C	P	P	P	MAGN.=AMM.	S	B
Nitric	N	S	P	N	SS	P	S	P	P	F	F	F	GLYCINA	N	C
Muriatic	M	P	SS	M	F	SS	SS	SS	F	B	B	SS	ALUMINA	M	P
Phosphoric	SS	SS	N	SS	P	F	F	F	B	SS	C	S	ZIRCONIA	P	F
Sulphurous	P	N	M	C	B	B	B	B	SS	S	SS	B	Each with every	F	SS
Fluoric	C	M	F	B	S	C	C	N	S	C	S	N	subsequent base	SS	S
Boracic	B	F	B	F	M	N	N	M	M	N	N	M	in this order,	B	N
Carbonic	F	B	C	P	N	M	M	C	N	M	M	C		C	M
STRONTIA	LM	PT	MG	LM	PT	MG	AM	GI	PT	MG	AM	GL			AM
		SD	AM		SD			AL	SD			AL			
			GL					ZR				ZR			
			AL												
			ZR												

The comparative use of this Table may be understood from an example: If we suppose that the nitrate of barita decomposes the borate of ammonia, we must place the boracic acid above the nitric, between barita and ammonia in this Table, and consequently barita below ammonia, between the fluoric and boracic in the former: hence the boracic and fluoric acids must also be transposed between barita and strontia, and between barita and potash; or if we place the fluoric still higher than the boracic in the first instance, we must place barita below ammonia between the nitric and fluoric acids, where indeed it is not impossible that it ought to stand.

IV. *A Numerical Table of Elective Attractions, by* Dr. YOUNG.

BARITA.		STRONTIA.		POTASH.		SODA.	LIME.	
Sulphuric acid	1000*	Sulphuric acid	903*	Sulphuric acid	894*	885*	Oxalic acid	960
Oxalic	950	Phosphoric	827*	Nitric	812*	804*	Sulphuric	868*
Succinic	930	Oxalic	825	Muriatic	804*	797*	Tartaric	867
Fluoric		Tartaric	757	Phosphoric	801*	795*	Succinic	866
Phosphoric	906*	*Fluoric*		Suberic ?	745	740	Phosphoric	865*
Mucic	900	Nitric	754*	Fluoric	671*	666*	Mucic	860
Nitric	849*	Muriatic	748*	Oxalic	650	645	Nitric	741*
Muriatic	840*	(Succinic)	740	Tartaric	616	611	Muriatic	736*
Suberic	800	(Fluoric)	703	Arsenic	614	609	Suberic	735
Citric		*Succinic*		Succinic	612	607	Fluoric	734*
Tartaric	760	Citric ?	618	Citric	610	605	Arsenic	733¾
Arsenic	733½	Lactic	603	Lactic	609	604	*Lactic*	732
(Citric)	730	*Sulphurous*	527*	Benzoic	608	603	Citric	731
Lactic	729	*Acetic*		Sulphurous	488*	484*	Malic	700
(Fluoric)	706*	*Arsenic*	(733¼)	Acetic	486	482	Benzoic	590
Benzoic	597	Boracic	513*	Mucic	484	480	*Acetic*	
Acetic	594	(Acetic)	480	Boracic	482*	479*	Boracic	537*
Boracic	(515)*	Nitrous ?	430	Nitrous	440	437	Sulphurous	516*
Sulphurous	592*	Carbonic	419*	Carbonic	306*	304*	(Acetic)	470
Nitrous	450			Prussic	300	298	Nitrous	425
Carbonic	420*						*Carbonic*	423*
Prussic	400						Prussic	290

MAGNESIA.		AMMONIA.		GLYCINA ?		ALUMINA.	ZIRCONIA?
Oxalic acid	820	Sulphuric acid	808*	Sulphuric acid	718*	709*	700*
Phosphoric		Nitric	731*	Nitric	642*	634*	626
Sulphuric	810*	Muriatic	729*	Muriatic	639*	632*	625*
(Phosphoric)	736*	Phosphoric	728*	Oxalic	600	594	588
Fluoric		Suberic ?	720	Arsenic	580	575	570
Arsenic	733	Fluoric	613*	Suberic ?	535	530	525
Mucic	732½	Oxalic	611	Fluoric	534*	529*	524*
Succinic	732¼	Tartaric	609	Tartaric	520	515	510
Nitric	732*	Arsenic	607	Succinic	510	505	500
Muriatic	728*	Succinic	605	Mucic	425	420	415
Suberic ?	700	Citric	603	Citric	415	410	405
(Fluoric)	620*	Lactic	601	*Phosphoric*	(648)*	(642)*	(636)*
Tartaric	618	Benzoic	599	Lactic	410	405	400
Citric	615	Sulphurous	433*	Benzoic	400	395	390
Malic ?	600?	Acetic	432	Acetic	395	391	387
Lactic	575	Mucic	431	Boracic	388*	385*	382*
Benzoic	560	Boracic	430*	Sulphurous	355*	351*	347*
Acetic		Nitrous	400	Nitrous	340	338	332
Boracic	459*	Carbonic	339*	Carbonic	325*	323*	321*
Sulphurous	439*	Prussic	270	Prussic	260	258	256
(Acetic)	430						
Nitrous	410						
Carbonic	366*						
Prussic	280						

Acids.

SULPHURIC.		NITRIC.		MURIATIC.		PHOSPHORIC.	
Barita	1000*	Barita	849*	Barita	840*	Barita	906*
Strontia	903*	Potash	812*	Potash	804*	Strontia	827*
Potash	894*	Soda	804*	Soda	797*	*Lime*	(865)*
Soda	885*	Strontia	754*	Strontia	748*	Potash	801*
Lime	868*	Lime	741*	Lime	736*	Soda	795*
Magnesia	810*	Magnesia	732*	Ammonia	729*	*Ammonia*	(728)*
Ammonia	808*	Ammonia	731*	Magnesia	728*	Magnesia	736*
Glycina	718*	Glycina	642*	Glycina	639*	Glycina	648*
Itria	712	Alumina	634*	Alumina	632*	Alumina	642*
Alumina	709*	Zirconia	626*	Zirconia	625*	Zirconia	636*
Zirconia	700*						

FLUORIC.		OXALIC.		TARTARIC.	ARSENIC.		TUNGSTIC.
Lime	734*	Lime	960	867	Lime	733¾	Lime
Barita	706*	Barita	930	760	Barita	733½	Barita
Strontia	703*	Strontia	825	757	Strontia	733¼	Strontia
Magnesia	(620)*	Magnesia	820	618	Magnesia	733	Magnesia
Potash	671*	Potash	650	616	Potash	614	Potash
Soda	666*	Soda	645	611	Soda	609	Soda
Ammonia	613*	Ammonia	611	609	Ammonia	607	Ammonia
Glycina	534*	Glycina ?	600	520	Glycina	580	Glycina
Alumina	529*	Alumina	594	515	Alumina	575	Alumina
Zirconia	524*	Zirconia ?	588	510	Zirconia	570	Zirconia

SUCCINIC.		SUBERIC.		CAMPHORIC.	CITRIC.	
Barita	930	Barita	800	Lime	Lime	731
Lime	866	Potash	745	Potash	Barita	730
Strontia ?	740	Soda	740	Soda	Strontia	618
(Magnesia)	732¼	Lime	735	Barita	Magnesia	615
Potash	612	Ammonia	720	Ammonia	Potash	610
Soda	607	Magnesia	700	Glycina ?	Soda	605
Ammonia	605	Glycina ?	535 ?	Alumina	Ammonia	603
Magnesia		Alumina	530	Zirconia ?	Glycina ?	415 ?
Glycina ?	510	Zirconia ?	525 ?	Magnesia	Alumina	410
Alumina	505				Zirconia	405
Zirconia ?	500					

LACTIC.		BENZOIC.		SULPHUROUS.		ACETIC.	
Barita	729	White oxide of arsenic		Barita	592*	Barita	594
Potash	609	Potash	608	Lime	516*	Potash	486
Soda	604	Soda	603	Potash	488*	Soda	482
Strontia	603	Ammonia	599	Soda	484*	*Strontia*	480
Lime	(732)	Barita	597	*Strontia*	(527)*	*Lime*	470
Ammonia	601	Lime	590	Magnesia	439*	Ammonia	432
Magnesia	575	Magnesia	560	Ammonia	433*	Magnesia	430
Metallic oxides		Glycina ?	400 ?	Glycina	355*	Metallic oxides	
Glycina	410	Alumina	395	Alumina	351*	Glycina	395
Alumina	405	Zirconia ?	390 ?	Zirconia	347*	Alumina	391
Zirconia	400					Zirconia	387

MUCIC ?		BORACIC.		NITROUS ?		PHOSPHOROUS.
Barita	900	Lime	537*	Barita	450	Lime
Lime	860	Barita	515*	Potash	440	Barita
Potash	484	Strontia	513*	Soda	437	Strontia
Soda	480	*Magnesia*	(459)*	Strontia	430	Potash
Ammonia	431	Potash	482*	Lime	425	Soda
Glycina	425	Soda	479*	Magnesia	410	Magnesia ?
Alumina	420	Ammonia	430*	Ammonia	400	Ammonia
Zirconia	415	Glycina	388*	Glycina	340	Glycina
		Alumina	385*	Alumina	336	Alumina
		Zirconia	382*	Zirconia	332	Zirconia

CARBONIC.		PRUSSIC.	
Barita	420*	Barita	400
Strontia	419*	Strontia	
Lime	(423)*	Potash	300
Potash ?	306*	Soda	298
Soda	304*	Lime	290
Magnesia	(366)*	Magnesia	280
Ammonia	339*	Ammonia	270
Glycina	325*	Glycina ?	260
Alumina	323*	Alumina ?	258
Zirconia	321*	Zirconia ?	256

TABLES

OF

SIMPLE ELECTIVE ATTRACTIONS,

FROM BERGMANN.

I.—WATER AND COMBUSTIBLE SUBSTANCES.

IN THE HUMID WAY.

Water.	Sulphur.	Saline Sulphurets.	Alcohol.	Ether.
Potash	Oxygen	Oxygen	Water	Alcohol
Soda	Molybdic oxide and acid	Oxide of gold	Ether	Volatile oils
Ammonia	Oxide of lead	silver	Volatile oils	Water
Deliquescent salts	tin	mercury	Ammonia	Sulphur
Alcohol	silver	arsenic	Fixed alkali	
Carbonate of ammonia	mercury	antimony	Alkaline sulphurets	
Ether	arsenic	bismuth	Sulphur	
Sulphuric acid	antimony	copper	Muriates	
Non-deliquescent salts	iron	tin	Phosphoric acid	
	Potash	lead		
	Soda	nickel		
	Barytes	cobalt		
	Strontian	manganese		
	Lime	iron		
	Magnesia	Other metallic oxides		
	Phosphorus	Carbon		
	Fat oils	Water		
	Ammonia	Alcohol		
	Ether	Ether		
	Hydrogen?			

Fat Oils.	Volatile Oils.
Barytes?	Ether
Strontian ?	Alcohol
Lime	Fat oils
Metallic oxides	Fixed alkalis
Ether	Sulphur
Volatile oils	Phosphorus
Fixed alkalis	
Ammonia	
Sulphur	
Phosphorus	

Sulphuretted Hydrogen.
Barytes
Potash
Soda
Lime
Ammonia
Magnesia
Zircon

IN THE DRY WAY.

Sulphur.	Saline Sulphurets.
Oxygen	Manganese
Potash	Iron
Soda	Copper
Iron	Tin
Copper	Lead
Tin	Silver
Lead	Gold
Silver	Antimony
Cobalt	Cobalt
Nickel	Nickel
Bismuth	Bismuth
Antimony	Mercury
Mercury	Arsenic
Arsenic	Carbon ?
Uranium ?	
Molybdena	
Tellurium	

TABLE of Simple Elective Attractions.

II.—OXYGEN AND METALS.

IN THE HUMID WAY.

Oxygen.	Oxide of Gold.	Oxide of Silver.	Oxide of Platina.	Oxide of Mercury.	Oxide of Lead.
Zinc	Acids, gallic	Acids, gallic	Acids, gallic	Acids, gallic	Acids, gallic
Iron	muriatic	muriatic	muriatic	muriatic	sulphuric
Tin	nitric	oxalic	nitric	oxalic	mucic
Antimony	sulphuric	sulphuric	sulphuric	succinic	oxalic
Arsenic	arsenic	mucic	arsenic	phosphoric	arsenic
Lead	fluoric	phosphoric	fluoric	sulphuric	tartaric
Bismuth	tartaric	sulphurous	tartaric	mucic	phosphoric
Copper	phosphoric	nitric	phosphoric	tartaric	muriatic
Platinum	acetic	arsenic	oxalic	citric	sulphurous
Mercury	sebacic	fluoric	citric	malic	suberic
Palladium	prussic	tartaric	acetic	sulphurous	nitric
Rhodium	Fixed alkalis	citric	succinic	nitric	fluoric
Iridium	Ammona	succinic	prussic	fluoric	citric
Osmium	Sulphuretted hydrogen	acetic	carbonic	acetic	malic
Silver		prussic	Ammonia	benzoic	succinic
Gold		carbonic		boracic	acetic
		Ammonia		prussic	benzoïc
				carbonic	boracic
				Ammonia	prussic
					carbonic
					Fixed alkalis
					Fat oils
					Ammonia

IN THE DRY WAY.

	Gold.	Silver.	Platina.	Mercury.	Lead.
Titanium	Mercury	Lead	Arsenic	Gold	Gold
Manganese	Copper	Copper	Gold	Silver	Silver
Zinc	Silver	Mercury	Copper	Platina	Copper
Iron	Lead	Bismuth	Tin	Lead	Mercury
Tin	Bismuth	Tin	Bismuth	Tin	Bismuth
Uranium	Tin	Gold	Zinc	Zinc	Tin
Molybdena	Antimony	Antimony	Antimony	Bismuth	Antimony
Tungsten	Iron	Iron	Nickel	Copper	Platina
Cobalt	Platina	Manganese	Cobalt	Antimony	Arsenic
Antimony	Zinc	Zinc	Manganese	Arsenic	Zinc
Nickel	Nickel	Arsenic	Iron	Iron	Nickel
Arsenic	Arsenic	Nickel	Lead	Alkaline sulphurets	Iron
Chromium	Cobalt	Platina	Silver	Sulphur	Alkaline sulphurets
Bismuth	Manganese	Alkaline sulphurets	Mercury		Sulphur
Lead	Alkaline sulphurets		Alkaline sulphurets		
Copper					
Tellurium					
Platinum					
Mercury					
Silver					
Gold					
Hydrogen					
Carbon					
Boron					
Phosphorus					
Sulphur					
Azote					
Chlorine					

The column under oxygen is divided into two parts. The first exhibits the order in which the metals precipitate one another from acid solutions; the second, according to Vauquelin, shows the affinities of the metals for oxygen, represented by the difficulty with which their oxides are decomposed by heat. It is different from Bergmann's column.

TABLE of Simple Elective Attractions.

METALS—(continued).

IN THE HUMID WAY.

Oxide of Copper.	Oxide of Iron.	Oxide of Tin.	Oxide of Bismuth.	Oxide of Nickel.	Oxide of Arsenic.
Acids, gallic	Acids, gallic	Acids, gallic	Acids, oxalic	Acids, oxalic	Acids, gallic
oxalic	oxalic	tartaric	arsenic	muriatic	muriatic
tartaric	tartaric	muriatic	tartaric	sulphuric	oxalic
muriatic	camphoric	sulphuric	phosphoric	tartaric	sulphuric
sulphuric	sulphuric	oxalic	sulphuric	nitric	nitric
mucic	mucic	arsenic	muriatic	sebacic	sebacic
nitric	muriatic	phosphoric	nitric	phosphoric	tartaric
arsenic	nitric	nitric	fluoric	fluoric	phosphoric
phosphoric	phosphoric	succinic	mucic	mucic	fluoric
succinic	arsenic	fluoric	succinic	succinic	mucic
fluoric	fluoric	mucic	citric	citric	succinic
citric	succinic	citric	acetic	acetic	citric
acetic	citric	acetic	prussic	arsenic	arsenic
boracic	acetic	boracic	carbonic	boracic	acetic
prussic	boracic	prussic	Ammonia	prussic	prussic
carbonic	prussic	Potash		carbonic	Fixed alkalis
Potash	carbonic	Soda		Ammonia	Ammonia
Soda		Ammonia			Fat oils
Ammonia					Water
Compound salts					
Fat oils					

IN THE DRY WAY.

Copper.	Iron.	Tin.	Bismuth.	Nickel.	Arsenic.
Gold	Nickel	Zinc	Lead	Iron	Nickel
Silver	Cobalt	Mercury	Silver	Cobalt	Cobalt
Iron	Manganese	Copper	Gold	Arsenic	Copper
Arsenic	Arsenic	Antimony	Mercury	Copper	Iron
Manganese	Copper	Gold	Antimony	Gold	Silver
Zinc	Gold	Silver	Tin	Tin	Tin
Antimony	Silver	Lead	Copper	Antimony	Lead
Platina	Tin	Iron	Platina	Platina	Gold
Tin	Antimony	Manganese	Nickel	Bismuth	Platina
Lead	Platina	Nickel	Iron	Lead	Zinc
Nickel	Bismuth	Arsenic	Zinc	Silver	Antimony
Bismuth	Lead	Platina	Alkaline sulphurets	Zinc	Alkaline sulphurets
Cobalt	Alkaline sulphurets	Bismuth	Sulphur	Alkaline sulphurets	Sulphur
Mercury	Sulphur	Cobalt		Sulphur	
Alkaline sulphurets		Alkaline sulphurets			
Sulphur		Sulphur			

TABLE of Simple Elective Attractions.

METALS—(concluded.)

IN THE HUMID WAY.

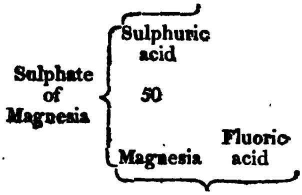
Oxide of Cobalt.	Oxide of Zinc.	Oxide of Antimony.	Oxide of Manganese.	Oxide of Tellurium.	Oxide of Titanium.
Acids, oxalic	Acids, gallic	Acids, gallic	Acids, oxalic	Acids, nitric	Acids, sulphuric
muriatic	oxalic	muriatic	tartaric	nitro-muriatic	nitric
sulphuric	sulphuric	benzoic	citric	sulphuric	muriatic
tartaric	muriatic	oxalic	fluoric	Sulphur	prussic
nitric	mucic	sulphuric	phosphoric	Alkalis	
phosphoric	nitric	nitric	nitric	Mercury	
fluoric	tartaric	tartaric	sulphuric		
mucic	phosphoric	mucic	muriatic		
succinic	citric	phosphoric	arsenic		
citric	succinic	citric	acetic		
acetic	fluoric	succinic	prussic		
arsenic	arsenic	fluoric	carbonic		
boracic	acetic	arsenic			
prussic	boracic	acetic			
carbonic	prussic	boracic			
Ammonia	carbonic	prussic			
	Fixed alkalis	carbonic			
	Ammonia	Sulphur			
		Fixed alkalis			
		Ammonia			

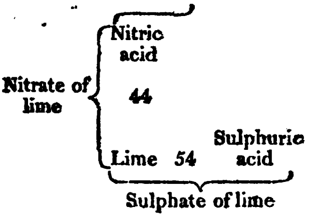
Oxide of Uranium.
Acids, sulphuric
nitro-muriatic
muriatic
nitric
phosphoric
acetic
gallic
prussic
carbonic
Sulphur

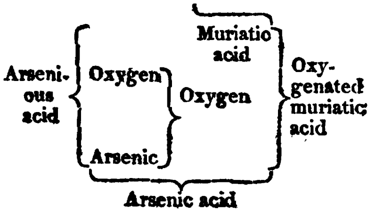
IN THE DRY WAY.

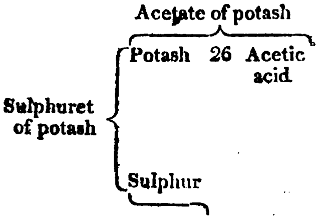
Cobalt.	Zinc.	Antimony.	Manganese.	Tellurium.
Iron	Copper	Iron	Copper	Mercury
Nickel	Antimony	Copper	Iron	Sulphur
Arsenic	Tin	Tin	Gold	
Copper	Mercury	Lead	Silver	
Gold	Silver	Nickel	Tin	
Platina	Gold	Silver	Alkaline sulphurets	
Tin	Cobalt	Bismuth		
Antimony	Arsenic	Zinc		
Zinc	Platina	Gold		
Alkaline sulphurets	Bismuth	Platina		
Sulphur	Lead	Mercury		
	Nickel	Arsenic		
	Iron	Cobalt		
		Alkaline sulphurets		
		Sulphur		

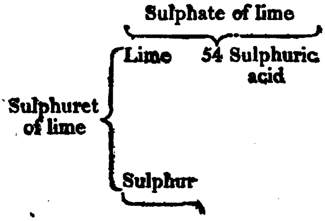
SCHEMES OF DOUBLE AFFINITIES IN THE HUMID WAY.

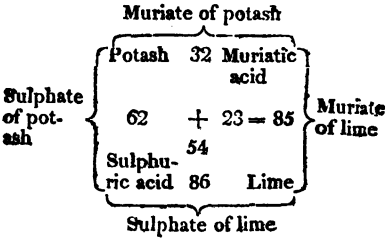


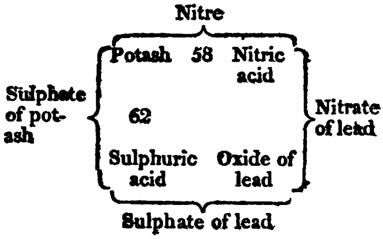


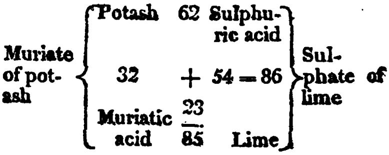


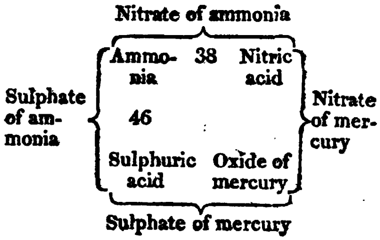


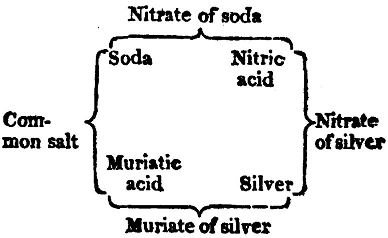












* Augite. Pyroxene of Haüy. This mineral is for the most part crystallized in small six or eight-sided prisms, with dihedral summits. It is found also in grains. Its colours are green, brown, and black. Internal luster shining. Uneven fracture. Translucent. Easily broken. It Scratches glass. Sp. gr. 3.3. Melts into a black enamel. Its composition according to Klaproth, is 48 silica, 24 lime, 12 oxide of iron, 8.75 magnesia, 5 alumina, 1 manganese. It is met with among volcanic rocks but is supposed to have existed prior to the eruption, and ejection of the lava. Large crystals of it are also found in basalt, of a finer green and more brilliant than those found in lavas. It occurs with olivin in the basalt of Teesdale; in the trap rocks round Edinburgh; and in several of the Hebrides.

Sahlite and coccolite are considered to be varieties of augite.*

Aurum Fulminans. See Fulminating.

* Aurum Graphicum. See Ores of Gold*

Aurum Musivum, or Mosaicum. A combination of tin and sulphur, which is thus made: Melt 12 ounces of tin, and add to it three ounces of mercury; triturate this amalgam with seven ounces of sulphur and three of muriate of ammonia. Put the powder into a matrass, bedded rather deep in sand, and keep it for several hours in a gentle heat; which is afterward to be raised, and continued for several hours longer. If the heat have been moderate and not continued too long, the golden-coloured scaly porous mass, called aurum musivum, will be found at the bottom of the vessel; but if it have been too strong, the aurum musivum fuses to a black mass of a striated texture. This process is thus explained: As the heat increases, the tin, by stronger affinity, seizes and combines with the muriatic acid of the muriate of ammonia; while the alkali of that salt, combining with a portion of the sulphur, flies off in the form of a sulphuret. The combination of tin and muriatic acid sublimes; and is found adhering to the sides of the matrass. The mercury which served to divide the tin, combines with part of the sulphur, and forms cinnabar, which also sublimes; and the remaining sulphur, with the remaining tin forms the aurum musivum, which occupies the lower part of the vessel. It must be admitted, however, that this explanation does not indicate the reasons why such an indirect and complicated process should be required to form a simple combination of tin and sulphur.

It does not appear that the proportions of the materials require to be strictly attended to. The process of the Marquis de Bullion, as described by Chaptal in his Elements of Chemistry, consists in amalgamating eight ounces of tin with eight ounces of mercury, and mixing this with six ounces of sulphur, and four of muriate of ammonia. This mixture is to be exposed for three hours on a sand heat sufficient to render the bottom of the matrass obscurely red-hot. But Chaptal himself found, that if the matrass containing the mixture were exposed to a naked fire and violently heated, the mixture took fire and a sublimate was formed in the neck of the matrass, consisting of the most beautiful aurum musivum in large hexagonal plates.

Aurum musivum has no taste, though some specimens exhibit a sulphureous smell. It is not soluble in water, acids, or alkaline solutions. But in the dry way it forms a yellow sulphuret, soluble in water. It deflagrates with nitre. Bergmann mentions a native aurum musivum from Siberia, containing tin, sulphur, and a small proportion of copper.

Aurum musivum is used as a pigment for giving a golden colour to small statue or plaster figures. It is likewise said to be mixed with melted glass to imitate lapis lazuli.

* Mosaic gold is composed of 100 tin + 56.25 sulphur, by Dr. John Davy; and of 100 tin + 52.3 sulphur, by Professor Berzelius; the mean of which, or 100 + 54.2 is probably correct. It will then consist of 1 prime of tin = 7.375 + 2 sulphur = 4.04.*

* Avanturine. A variety of quartz rock containing mica spangles. The most beautiful comes from Spain, but Dr. M'Culloch found specimens at Glen Fernat in Scotland, which, when polished, were equal in beauty to any of the foreign. The most usual colour of the base of avanturine is brown, or reddish-brown, enclosing golden coloured spangles.*

* Axe-stone. A subspecies of jade, from which it differs in not being of so light a green, and in having a somewhat slaty texture. The natives of New Zealand work it into hatchets. It is found in Corsica, Switzerland, Saxony, and on the banks of the river Amazons, whence it has been called Amazonian stone. Its constituents are silica 50.5, magnesia 31, alumina 10, oxide of iron 5.5, water 2.75, oxide of chromium 0.05.*

* Axinite, or Thumerstone. This mineral is sometimes massive, but most usually crystallized. The crystals resemble an axe in the form and sharpness of their edges; being flat rhomboidal parallelopipeds, with two of the opposite edges wanting, and a small face instead of each. They are translucent, and of a violet colour, whence called violet schorl. They become electric by heat. The usual colour is clove-brown. Lustre splendent.

Hard, but yields to the file, and easily broken. Sp. gr. 3.25. It froths like zeolite before the blow-pipe, melting into a black enamel, or a dark green glass. According to Vauquelin's analysis, it contains 44 silica, 18 alumina, 19 lime, 14 oxide of iron, and 4 oxide of manganese. It is found in beds at Thum in Saxony; in Killas at Botallack near the Land's-end, Cornwall; and at Trewellard in that neighbourhood.*

AZOTE. See GAS (NITROGEN).

* AZURE-STONE, or LAPIS LAZULI. This massive mineral is of a fine azure blue colour. Lustre glistening. Fine grained uneven fracture. Scratches glass, but scarcely strikes fire with steel. Opaque, or translucent on the very edges. Easily broken. Sp. grav. 2.85. In a very strong heat it intumesces, and melts into a yellowish-black mass. After calcination it forms a jelly with acids. It consists of 46 silica, 28 lime, 14.5 alumina, 3 oxide of iron, 6.5 sulphate of lime, and 2. water, according to Klaproth. But by a later and most interesting research of MM. Clement and Desormes, lapis lazuli appears to be composed of 34 silica, 33 alumina, 3 sulphur, and 22 soda. (Ann. de Chimie, tom. 57.) In this analysis, however, a loss of eight per cent was experienced. These distinguished chemists consider the above ingredients essential, and the 2.4 of lime and 1.5 of iron, which they have occasionally met with, as accidental. It is from azure-stone that the beautiful and unchangeable blue colour ultramarine is prepared. The finest specimens are brought from China, Persia, and Great Bucharia. They are made red-hot in the fire, and thrown into water to render them easily pulverizable. They are then reduced to a fine powder, and intimately combined with a varnish, formed of resin, wax, and boiled linseed oil. This pasty mixture is put into a linen cloth, and repeatedly kneaded with hot water: the first water, which is usually dirty, is thrown away; the second gives a blue of the first quality; and the third yields one of less value. The process is founded on the property which the colouring matter of azure-stone has of adhering less firmly to the resinous cement, than the foreign matter with which it is associated. When azure-stone has its colour altered by a moderate heat, it is reckoned bad. Messrs. Clement and Desormes consider the extraction of ultramarine as a species of saponification.*

* AZURITE, the LAZULITE of Werner and Haüy. This mineral is often found in oblique quadrangular crystals of a fine blue colour. It is translucent only on the edges, brittle, and nearly as hard as quartz. When massive, it is either in grains, or bits like a hazel nut. It occurs imbedded in mica slate. Its lustre is vitreous. Its constituents are 66 alumina, 18 magnesia, 10 silica, 2.5 oxide of iron, 2 lime. It occurs in Vorau in Stiria in a gangue of quartz; but the finest specimens come from the bishopric of Salzburg.*

B

BALANCE. The beginning and end of every exact chemical process consists in weighing. With imperfect instruments this operation will be tedious and inaccurate; but with a good balance, the result will be satisfactory; and much time, which is so precious in experimental researches, will be saved.

The balance is a lever, the axis of motion of which is formed with an edge like that of a knife; and the two dishes at its extremities are hung upon edges of the same kind. These edges are first made sharp, and then rounded with a fine hone, or a piece of buff leather. The excellence of the instrument depends, in a great measure, on the regular form of this rounded part. When the lever is considered as a mere line, the two outer edges are called points of suspension, and the inner the fulcrum. The points of suspension are supposed to be at equal distances from the fulcrum, and to be pressed with equal weights when loaded.

1. If the fulcrum be placed in the centre of gravity of the beam, and the three edges lie all in the same right line, the balance will have no tendency to one position more than another, but will rest in any position it may be placed in, whether the scales be on or off, empty or loaded.

2. If the centre of gravity of the beam, when level, be immediately above the fulcrum, it will overset by the smallest action; that is, the end which is lowest will descend: and it will do this with more swiftness, the higher the centre of gravity, and the less the points of suspension are loaded.

3. But if the centre of gravity of the beam be immediately below the fulcrum, the beam will not rest in any position but when level: and, if disturbed from this position, and then left at liberty, it will vibrate, and at last come to rest on the level. Its vibrations will be quicker, and its horizontal tendency stronger, the lower the centre of gravity, and the less the weights upon the points of suspension.

4. If the fulcrum be below the line joining the points of suspension, and these be loaded, the beam will overset, unless prevented by the weight of the beam tending to produce a horizontal position, as in § 3. In this last case, small weights will equilibrate, as in § 3.; a certain exact weight will rest in any position of the beam, as in § 1.; and all greater weights will cause the beam to overset, as in § 2. Many scales are often made this way, and will overset with any considerable load.

5. If the fulcrum be above the line joining the points of suspension, the beam will come to the horizontal position, unless prevented by its own weight, as in § 2. If the centre of gravity of the beam be nearly in the fulcrum, all the vibrations of the loaded beam will be made in times nearly equal, unless the weights be very small, when they will be slower. The vibrations of balances are quicker, and the horizontal tendency stronger, the higher the fulcrum.

6. If the arms of a balance be unequal, the weights in equipoise will be unequal in the same proportion. It is a severe check upon a workman to keep the arms equal, while he is making the other adjustments in a strong and inflexible beam.

7. The equality of the arms of a balance is of use, in scientific pursuits, chiefly in making weights by bisection. A balance with unequal arms will weigh as accurately as another of the same workmanship with equal arms, provided the standard weight itself be first counterpoised, then taken out of the scale, and the thing to be weighed be put into the scale, and adjusted against the counterpoise; or when proportional quantities only are considered, as in chemical and in other philosophical experiments, the bodies and products under examination may be weighed against the weights, taking care always to put the weights into the same scale. For then, though the bodies may not be really equal to the weights, yet their proportions among each other may be the same as if they had been accurately so.

8. But though the equality of the arms may be well dispensed with, yet it is indispensably necessary, that their relative lengths, whatever they may be, should continue invariable. For this purpose, it is necessary, either that the three edges be all truly parallel, or that the points of suspension and support should be always in the same part of the edge. This last requisite is the most easily obtained.

The balances made in London are usually constructed in such a manner, that the bearing parts form notches in the other parts of the edges; so that the scales being set to vibrate, all the parts naturally fall into the same bearing. The balances made in the country have the fulcrum edge straight, and confined to one constant bearing by two side plates. But the points of suspension are referred to notches in the edges, like the London balances. The balances here mentioned, which come from the country, are enclosed in a small iron japanned box; and are to be met with at the Birmingham and Sheffield warehouses, though less frequently than some years ago; because a pocket contrivance for weighing guineas and half-guineas has got possession of the market. They are, in general, well made and adjusted, turn with the twentieth of a grain when empty, and will sensibly show the tenth of a grain, with an ounce in each scale. Their price is from five shillings to half a guinea; but those which are under seven shillings have not their edges hardened, and consequently are not durable. This may be ascertained by the purchaser, by passing the point of a penknife across the small piece which goes through one of the end boxes: if it makes any mark or impression, the part is soft.

9. If a beam be adjusted so as to have no tendency to any one position, as in § 1. and the scales be equally loaded; then, if a small weight be added in one of the scales, that balance will turn, and the points of suspension will move with an accelerated motion, similar to that of falling bodies, but as much slower, in proportion, very nearly, as the added weight is less than the whole weight borne by the fulcrum.

10. The stronger the tendency to a horizontal position in any balance, or the quicker its vibrations, §§ 3. 5. the greater additional weight will be required to cause it to turn, or incline to any given angle. No balance, therefore, can turn so quick as the motion deduced in § 9. Such a balance as is there described, if it were to turn with the ten-thousandth part of the weight, would move at quickest ten thousand times slower than falling bodies; that is, the dish containing the weight, instead of falling through sixteen feet in a second of time, would fall through only two hundred parts of an inch, and it would require four seconds to move through one-third part of an inch; consequently all accurate weighing must be slow. If the indexes of two balances be of equal lengths, that index which is connected with the shorter balance will move proportionally quicker than the other. Long beams are the most in request, because they are thought to have less friction; this is doubtful; but the quicker angular motion, greater strength, and less weight of a short balance, are certainly advantages.

11. Very delicate balances are not only useful in nice experiments, but are likewise much more expeditious than others in common weighing. If a pair of scales with a certain load be barely sensible to one-tenth of a grain, it will require a considerable time to ascertain the weight to that degree of accuracy, because the turn must be observed several times over, and is very small. But if no greater accuracy were required, and scales were used, which would turn with the hundredth of a grain, a tenth of a grain, more or less, would make so great a difference in the turn, that it would be seen immediately.

12. If a balance be found to turn with a certain addition, and is not moved by any smaller weight, a greater sensibility may be given to that balance, by producing a tremulous motion in its parts. Thus, if the edge of a blunt saw, a file, or other similar instrument, be drawn along any part of the case or support of a balance, it will produce a jarring, which will diminish the friction on the moving parts so much, that the turn will be evident with one-third or one-fourth of the addition that would else have been required. In this way, a beam which would barely turn by the addition of one-tenth of a grain, will turn with one-thirtieth or fortieth of a grain.

13. A balance, the horizontal tendency of which depends only on its own weight, as in § 3. will turn with the same addition, whatever may be the load; except so far as a greater load will produce a greater friction.

14. But a balance, the horizontal tendency of which depends only on the elevation of the fulcrum, as in § 5. will be less sensible the greater the load; and the addition requisite to produce an equal turn will be in proportion to the load itself.

15. In order to regulate the horizontal tendency in some beams, the fulcrum is placed below the points of suspension, as in § 4. and a sliding weight is put upon the cock or index, by means of which the centre of gravity may be raised or depressed. This is a useful contrivance.

16. Weights are made by a subdivision of a standard weight. If the weight be continually halved, it will produce the common pile, which is the smallest number for weighing between its extremes, without placing any weight in the scale with the body under examination. Granulated lead is a very convenient substance to be used in this operation of halving, which, however, is very tedious. The readiest way to subdivide small weights, consists in weighing a certain quantity of small wire, and afterward cutting it into such parts, by measure, as are desired; or the wire may be wrapped close round two pins, and then cut asunder with a knife. By this means it will be divided into a great number of equal lengths, or small rings. The wire ought to be so thin, as that one of these rings may barely produce a sensible effect on the beam. If any quantity (as, for example, a grain) of these rings be weighed, and the number then reckoned, the grain may be subdivided in any proportion, by dividing that number, and making the weights equal to as many of the rings as the quotient of the division denotes. Then, if 750 of the rings amounted to a grain, and it were required to divide the grain decimally, downwards, 9-10ths would be equal to 675 rings, 8-10ths would be equal to 600 rings, 7-10ths to 525 rings, &c. Small weights may be made of thin leaf brass. Jewellers' foil is a good material for weights below 1-10th of a grain, as low as to 1-100th of a grain; and all lower quantities may be either esti-

mated by the position of the index, or shown by actually counting the rings of wire, the value of which has been determined.

17. In philosophical experiments, it will be found very convenient to admit no more than one dimension of weight. The grain is of that magnitude as to deserve the preference. With regard to the number of weights the chemists ought to be provided with, writers have differed according to their habits and views. Mathematicians have computed the least possible number, with which all weights within certain limits might be ascertained; but their determination is of little use. Because, with so small a number, it must often happen, that the scales will be heavily loaded with weights on each side, put in with a view only to determine the difference between them. It is not the least possible number of weights which it is necessary an operator should buy to effect his purpose, that we ought to inquire after, but the most convenient number for ascertaining his inquiries with accuracy and expedition. The error of adjustment is the least possible, when only one weight is in the scale; that is, a single weight of five grains is twice as likely to be true, as two weights, one of three, and the other of two grains, put into the dish to supply the place of the single five; because each of these last has its own probability of error in adjustment. But since it is as inconsistent with convenience to provide a single weight, as it would be to have a single character for every number; and as we have nine characters, which we use in rotation, to express higher values according to their position, it will be found very serviceable to make the set of weights correspond with our numerical system. This directs us to the set of weights as follows: 1000 grains, 900 g. 800 g. 700 g. 600 g. 500 g. 400 g. 300 g. 200 g. 100 g. 90 g. 80 g. 70 g. 60 g. 50 g. 40 g. 30 g. 20 g. 10 g. 9 g. 8 g. 7 g. 6 g. 5 g. 4 g. 3 g. 2 g. 1 g. $\frac{9}{10}$ g. $\frac{8}{10}$ g. $\frac{7}{10}$ g. $\frac{6}{10}$ g. $\frac{5}{10}$ g. $\frac{4}{10}$ g. $\frac{3}{10}$ g. $\frac{2}{10}$ g. $\frac{1}{10}$ g. $\frac{9}{100}$ g. $\frac{8}{100}$ g. $\frac{7}{100}$ g. $\frac{6}{100}$ g. $\frac{5}{100}$ g. $\frac{4}{100}$ g. $\frac{3}{100}$ g. $\frac{2}{100}$ g. $\frac{1}{100}$ g. With these the philosopher will always have the same number of weights in his scales, as there are figures in the number expressing the weights in grains.

Thus 742.5 grains will be weighed by the weights 700, 40, 2, and 5-10ths.

I shall conclude this chapter with an account of some balances I have seen or heard of, and annex a table of the correspondence of weights of different countries.

Muschenbroek, in his Cours de Physique, (French translation, Paris, 1769), tom. ii. p. 247. says, he used an ocular balance of great accuracy, which turned (trebuchoit) with $\frac{1}{40}$ of a grain. The substances he weighed were between 200 and 300 grains. His balance therefore weighed to the $\frac{1}{12000}$ part of the whole; and would ascertain such weights truly to four places of figures.

In the Philosophical Transactions, vol. lxvi. p. 509. mention is made of two accurate balances of Mr. Bolton; and it is said that one would weigh a pound, and turn with $\frac{1}{10}$ of a grain. This, if the pound be avoirdupois, is $\frac{1}{70000}$ of the weight; and shews that the balance could be well depended on to four places of figures, and probably to five. The other weighed half an ounce, and turned with $\frac{1}{100}$ of a grain. This is $\frac{1}{24000}$ of the weight.

In the same volume, p. 511. a balance of Mr. Read's is mentioned, which readily turned with less than one pennyweight, when loaded with 55 pounds, before the Royal Society; but very distinctly turned with four grains, when tried more patiently. This is about $\frac{1}{96000}$ part of the weight; and therefore this balance may be depended on to five places of figures.

Also, page 576. a balance of Mr. Whitehurst's weighs one pennyweight, and is sensibly affected with $\frac{1}{2000}$ of a grain. This is $\frac{1}{48000}$ part of the weight.

I have a pair of scales of the common construction, § 8. made expressly for me by a skilful workman in London. With 1200 grains in each scale, it turns with $\frac{1}{70}$ of a grain. This is $\frac{1}{84000}$ of the whole; and therefore about this weight may be known to five places of figures. The proportional delicacy is less in greater weights. The beam will weigh near a pound troy; and when the scales are empty, it is affected by $\frac{1}{1000}$ of a grain. On the whole, it may be usefully applied to determine all weights between 100 grains and 4000 grains to four places of figures.

A balance belonging to Mr. Alchorne of the Mint in London, is mentioned, vol. lxxvii. p. 205. of the Philosophical Transactions. It is true to 3 grains with 15 lb. an end. If these were avoirdupois pounds, the weight is known to $\frac{1}{30000}$ part, or to four places of figures, or barely five.

A balance, (made by Ramsden, and turning on points instead of edges) in the possession of Dr. George Fordyce, is mentioned in the seventy-fifth volume of the Philosophical Transactions. With a load of four or five ounces, a difference of one division in the index was made by $\frac{1}{1000}$ of a grain. This is $\frac{1}{384000}$ part of the weight, and consequently this beam will ascertain such weights to five places of figures, beside an estimate figure.

I have seen a strong balance in the possession of my friend Mr. Magellan, of the kind mentioned in § 15. which would bear several pounds, and showed $\frac{1}{10}$ of a grain, with one pound an end. This is $\frac{1}{70000}$ of the weight, and answers to five figures. But I think it would have done more by a more patient trial than I had time to make.

The Royal Society's balance, which was lately made by Ramsden, turns on steel edges, upon planes of polished crystal. I was assured, that it ascertained a weight to the seven-millionth part. I was not present at this trial, which must have required great care and patience, as the point of suspension could not have moved over much more than the $\frac{2}{100}$ of an inch in the first half minute; but, from some trials which I saw, I think it probable that it may be used in general practice to determine weights to five places and better.

From this account of balances, the student may form a proper estimate of the value of those tables of specific gravities, which are carried to five, six, and even seven places of figures, and likewise of the theoretical deductions in chemistry, that depend on a supposed accuracy in weighing, which practice does not authorise. In general, where weights are given to five places of figures, the last figure is an estimate, or guess figure; and where they are carried farther, it may be taken for granted; that the author deceives either intentionally, or from want of skill in reducing his weights to fractional expressions, or otherwise.

The most exact standard weights were procured, by means of the ambassadors of France, resident in various places; and these were compared by Mons. Tillet with the standard mark in the pile preserved in the Cour de Monnoies de Paris. His experiments were made with an exact balance made to weigh one marc, and sensible to one quarter of a grain. Now, as the marc contains 18432 quarter grains, it follows that this balance was a good one, and would exhibit proportions to four places, and a guess figure. The results are contained in the following table, extracted from Mons. Tillet's excellent paper in the Memoirs of the Royal Academy of Sciences for the year 1767. I have added the two last columns, which show the number of French and English grains contained in the compound quantities against which they stand. The English grains are computed to one-tenth of a grain, although the accuracy of weighing came no nearer than about two-tenths.

The weights of the kilogramme, gramme, decigramme, and centigramme, which are now frequently occurring in the French chemical writers, are added at the bottom of this table, according to their respective values.

Table of the Weights of different Countries.

Place and Denomination of Weights.	*marc.*	*oz.*	*gros.*	*grains.*	*F. grains.*	*E. grains.*
Berlin. The marc of 16 loths, - - - -	—	7	5	16	4408	3616.3
Berne. Goldsmiths' weight of 8 ounces,	1	—	½	4	4648	3813.2
Berne. Pound of 16 ounces, for merchandise, - - - - - - - -	2	1	½	6	9834	8067.7
The common pound varies very considerably in other towns of the canton.						
Berne. Apothecaries' weight of 8 ounces,	—	7	5½	26	4454	3654.
Bonn. - - - - - - - -	—	7	5	6¾	4398¾	3608.6
Brussels. The marc, or original troyes wt.	1	—	—	21	4629	3797.6
Cologn. The marc of 16 loths, - -	—	7	5	11	4403	3612.2
Constantinople. The cheki, or 100 drachms,	1	2	3	28	6004	4925.6
Copenhagen. Goldsmiths' weight, commonly supposed equal to the marc of Cologn,	—	7	5½	10⅓	4438⅓	3641.2
Copenhagen. Merchants' weight of 16 loths,	1	—	1	22½	4702½	3857.9
Dantzic weight, commonly supposed equal to the marc of Cologn,	—	7	5	3½	4395½	3606.
Florence. The pound (anciently used by the Romans),	1	3	½	20	6392	5244.
Genoa. The peso sottile, - - -	1	2	2½	30	5970	4897.7
Genoa. The peso grosso, - - -	1	2	3	5	5981	4906.7
Hamburgh weight, commonly supposed equal to the Cologn marc,	—	7	5	7¾	4399¾	3609.4
Hamburgh. Another weight, - -	—	7	7	23	4559	3740.2
Liege. The Brussels marc used; but the weight proved,	1	—	—	24	4632	3800.1
Lisbon. The marc, or half pound, - -		7	3½	34	4318	3542.4

Place and Denomination of Weights.	*marc.*	*oz.*	*gros.*	*grains.*	*F. grains.*	*E. grains.*
London. The pound troy, - - - -	1	4	1½	1	7021	5760.
London. The pound avoirdupois, - -	1	6	6½	6	8538	7004.5
Lucca. The pound, - - - - -	1	3	—	23	6359¼	5217.
Madrid. The marc royal of Castile, -	—	7	4	8¼	4328	3550.7
Malta. The pound, - - - - -	1	2	2½	21	5961	4890.4
Munheim. (The Cologn marc), - -	—	7	5	10	4402	3611.5
Milan. The marc, - - - - -	—	7	5	33¼	4425	3660.2
Milan. The libra grossa, - - - -	3	—	7½	—	14364½	11784.
Munich. (The Cologn marc), - -	—	7	5	11	4403½	3612.3
Naples. The pound of 12 ounces, - -	1	2	3½	27½	6039	4954.3
Ratisbon. The weight for gold: of 128 crowns	1	6	—	24	8088	6635.3
Ratisbon. The weight for ducats: of 64 ducats,	—	7	2	32	4208	3452.3
Ratisbon. The marc of 8 ounces, - -	1	—	—	24	4632	3800.1
Ratisbon. The pound of 16 ounces, - -	2	2	4½	6	10698	8776.5
Rome. The pound of 12 ounces, - -	1	3	½	14	6386	5239.
Stockholm. The pound of 2 marcs, - -	1	5	7	8	8000	6563.1
Stuttgard. (The Cologn marc), - -	—	7	5	11¾	4403¾	3612.6
Turin. The marc of 8 ounces, - -	1	—	—	22¼	4630¼	3799.
At Turin they have also a pound of 12 of the above ounces. But, in their apothecaries' pound of 12 ounces, the ounce is one-sixth lighter.						
Warsaw. The pound, - - - - -	1	5	2	12	7644	6271.
Venice. The libra grossa of 12 ounces, -	1	7	4½	25½	8989½	7374.5
Venice. The peso sottile of 12 ounces, -	1	1	6½	24	5676	4656.5
In the pounds dependent on Venice, the pound differs considerably in each.						
Vienna. The marc of commerce, - -	1	1	1	16	5272	4325.
Vienna. The marc of money, - -	1	1	1	26	5282	4333.3
England. The grain, - - - - -	—	—	—	—	1.21895	1.
France. The grain, - - - - -	—	—	—	—	1.	0.82039
The kilogramme, - - - -	4	—	5	35	18827.15	15445.5
The gramme, - - - -	—	—	—	—	18.827	15.445
The decigramme, - - - -	—	—	—	—	1.8827	1.5445
The centigramme, - - - -	—	—	—	—	.18827	.15445

See Tables of Weights and Measures in the Appendix.

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* The commissioners, appointed by the British government for considering the subject of weights and measures, gave in their first report on the 24th June 1819. The following is the substance of it:

"1. With respect to the actual magnitude of the standards of length, the commissioners are of opinion, that there is no sufficient reason for altering those generally employed, as there is no practical advantage in having a quantity commensurable to any original quantity existing, or which may be imagined to exist, in nature, except as affording some little encouragement to its common adoption by neighbouring nations.

"2. The subdivisions of weights and measures at present employed in this country, appear to be far more convenient for practical purposes than the decimal scale. The power of expressing a third, a fourth, and a sixth of a foot in inches, without a fraction, is a peculiar advantage in the duodecimal scale; and for the operation of weighing and of measuring capacities, the continual division by *two*, renders it practicable to make up any given quantity with the smallest possible number of weights and measures, and is far preferable in this respect to any decimal scale. The commissioners therefore recommend, that all the multiples and subdivisions of the standard to be adopted, should retain the same relative proportions to each other as are at present in general use.

"3. That the standard yard should be that employed by Gen. Roy in the measurement of a base on Hounslow Heath, as a foundation of the great trigonometrical survey.

"4. That in case this standard should be lost or impaired, it shall be declared, that the length of a pendulum, vibrating seconds of mean solar time in London, on the level of the sea, and in a vacuum, is 39.1372 inches of the standard scale, and that the length of the French metre, as the 10 millionth part of the quadrantal arc of the meridian, has been found equal to 39.3694 inches.

"5. That 10 ounces troy, or 4800 grains, should be declared equal to the weight of 19 cubic inches of distilled water, at the temperature of 50°, and that one pound avoirdupois must contain 7000 of these grains.

"6. That the standard ale and corn gallon should contain exactly *ten* pounds avoirdupois of distilled water at 62° Fahr. being nearly equal to 277.2 cubic inches, and agreeing with the standard pint in the Exchequer, which is found to contain exactly 20 ounces of water. The customary ale gallon contains 282 cubic inches, and the Winchester corn gallon 269, or according to other statutes 272¼ cubic inches; so that no inconvenience can possibly be felt from the introduction of a new gallon of 277.2 inches. The commissioners have not decided upon the propriety of abolishing entirely the use of the wine gallon."

The following elegantly simple relations of weight and measure were suggested by Dr. Wollaston, in his examination before the committee; and it is to be hoped they will be adopted in the national system:

"There is one standard of capacity that would be *particularly* advantageous, because it would bear simple proportions to the measures now in use, so that one of the great inconveniences arising from change of the standard would be obviated, by the facility of making many necessary computations without reference to tables.

"If the gallon measure be defined to be that which contains 10 lbs. of water at 56½° F.; then, since the cubic foot of water weighs 1000 oz. at 56½°,

½ pint = 10 oz. = $\frac{1}{100}$ cubic foot = 17.28 inches.
Pint = 20 oz. = 34.56 inches.
Bushel = 80 lb. = 2211.84

"And the simple proportions above alluded to will be found as follows:

	Cubic Inches.		
The gallon of 10 lb.	= 276.48 × $\frac{50}{49}$	= 282.01	282 beer gallon.
Also,	= 276.48 × $\frac{10}{12}$	= 230.40	231 wine gallon.
The pint of 1¼ lb.	= 34.56 × 3	= 103.68	103.4 Stirlg. jug.
Bushel of 80 lb.	= 2211.84 × $\frac{35}{36}$	= 2150.40	2150,42 Winch. bush.
A cylinder of 18¾ in. diam.	× 8	= 2208.93	Approximate bush.
Ditto 18¾	× 8.0105		221.184 new bush.

"The following mode of defining the standards of length, weight, and capacity, is submitted to the committee on weights and measures, as the most distinct answer to their inquiries:

One yard, of 36 inches, *is* such, that a pendulum of 39.13 inches, vibrates seconds in London.
Avoir. one pound, of 16 oz. *is* such, that one cubic foot of water at 56½°, weighs 1000 oz.
Troy. one pound, of 5760 grains, *is* such, that 7000 grains = 1 pound (avoirdupois).
One gallon, of 8 pints, *may be* such as to contain 10 pounds of distilled water at the temperature of 56½° Fahr. with great convenience."

Captain Kater has lately made a small correction on his first determination of the length of the pendulum vibrating seconds in the latitude of London. Instead of 39.13860 inches, as given in the Ph. Trans. for 1818, he has made it 39.13929 inches of Sir Geo. Shuckburgh's standard scale. Mr. Watts, in the 5th number of the Edinburgh Philosophical Journal, makes it = 39.138666 of the above scale, or = 39.1372405 of General Roy's scale, at Captain Kater's temperature of 62° Fahr. and 0.9941 of a metre.*

* **Baikalite.** See **Tremolite, asbestiform.***

Balas, or Balais Ruby. See **Spinelle.**

Balloon. Receivers of a spherical form are called balloons.

Balloon. See **Aerostatics.**

* **Balsams,** are vegetable juices, either liquid, or which spontaneously become concrete, consisting of a substance of a resinous nature, combined with benzoic acid, or which are capable of affording benzoic acid, by being heated alone, or with water. They are insoluble in water, but readily dissolve in alcohol and ether. The liquid balsams are copaiva, opobalsam, Peru, styrax, tolu; the concrete are benzoin, dragon's blood, and storax; which see.*

Balsam of Sulphur. A solution of sulphur in oil.

* **Baldwin's Phosphorus.** Ignited nitrate of lime.*

* **Barium.** The metallic basis of the earth barytes has been called barium by its discoverer, Sir H. Davy. Take pure barytes,

make it into a paste with water, and put this on a plate of platinum. Make a cavity in the middle of the barytes, into which a globule of mercury is to be placed. Touch the globule with the negative wire and the platinum with the positive wire, of a voltaic battery of about 100 pairs of plates in good action. In a short time an amalgam will be formed, consisting of mercury and barium. This amalgam must be introduced into a little bent tube, made of glass free from lead, sealed at one end, which being filled with the vapour of naphtha, is then to be hermetically sealed at the other end. Heat must be applied to the recurved end of the tube, where the amalgam lies. The mercury will distil over, while the barium will remain.

This metal is of a dark grey colour, with a lustre inferior to that of cast-iron. It is fusible at a red heat. Its density is superior to that of sulphuric acid; for though surrounded with globules of gas, it sinks immediately in that liquid. When exposed to air, it instantly becomes covered with a crust of barytes; and when gently heated in air, burns with a deep red light. It effervesces violently in water, converting this liquid into a solution of barytes. Sir H. Davy thinks it probable that barium may be procured by chemical as well as electrical decomposition. When chloride of barium, or even the dry earth, ignited to whiteness, is exposed to the vapour of potassium, a dark grey substance is found diffused through the barytes or the chloride, not volatile, which effervesces copiously in water, and possesses a metallic appearance, which disappears in the air. The potassium, by being thus transmitted, is converted into potash. From indirect experiments, Sir H. Davy was inclined to consider barytes as composed of 89.7 barium + 10.3 oxygen = 100. This would make the prime equivalent of barium 8.7, and that of barytes 9.7, compared to that of oxygen 1.0; a determination probably very exact. Dr. Clark of Cambridge, by exposing dry nitrate of barytes on charcoal, to the intense heat of the condensed hydroxygen flame, observed metallic globules in the midst of the boiling fluid, and the charcoal was found to be studded over with innumerable globules of a pure metal of the most brilliant lustre and whiteness. On letting these globules fall from the charcoal into water, hydrogen was evolved in a continued stream. When the globules are plunged in naphtha, they retain their brilliancy but for a few days.

Barium combines with oxygen in two proportions forming, 1st, barytes, and 2d, the deutoxide of barium.

Pure barytes is best obtained by igniting in a covered crucible, the pure crystallized nitrate of barytes. It is procured in the state of hydrate, by adding caustic potash or soda to a solution of the muriate or nitrate. And barytes, slightly coloured with charcoal, may be obtained by strongly igniting the carbonate and charcoal mixed together in fine powder. Barytes obtained from the ignited nitrate is of a whitish-grey colour; more caustic than strontites, or perhaps even lime. It renders the syrup of violets green, and the infusion of turmeric red. Its specific gravity by Fourcroy is 4. When water in small quantity is poured on the dry earth, it slakes like quicklime, but perhaps with evolution of more heat. When swallowed it acts as a violent poison. It is destitute of smell.

When pure barytes is exposed, in a porcelain tube, at a heat verging on ignition, to a stream of dry oxygen gas, it absorbs the gas rapidly, and passes to the state of deutoxide of barium. But when it is calcined in contact with atmospheric air, we obtain at first this deutoxide and carbonate of barytes; the former of which passes very slowly into the latter, by absorption of carbonic acid from the atmosphere.

The deutoxide of barium is of a greenish-grey colour; it is caustic, renders the syrup of violets green, and is not decomposable by heat or light. The voltaic pile reduces it. Exposed at a moderate heat to carbonic acid, it absorbs it, emitting oxygen, and becoming carbonate of barytes. The deutoxide is probably decomposed by sulphuretted hydrogen at ordinary temperatures. Aided by heat, almost all combustible bodies, as well as many metals, decompose it. The action of hydrogen is accompanied with remarkable phenomena. At about 392° F. the absorption of this gas commences; but at a heat approaching to redness it is exceedingly rapid, attended with luminous jets proceeding from the surface of the deutoxide. Although much water be formed, none of it appears on the sides of the vessel. It is all retained in combination with the protoxide, which in consequence becomes a hydrate, and thus acquires the property of fusing easily. By heating a certain quantity of barytes with an excess of oxygen in a small curved tube standing over mercury, M. Thenard ascertained, that in the deutoxide the quantity of the oxygen is the double of that in the protoxide. Hence the former will consist of 8.7 barium + 2 oxygen = 10.7 for its prime equivalent. From the facility with which the protoxide passes into the deutoxide, we may conceive that the former may frequently contain a proportion of the latter, to which cause may be ascribed in some degree the discrepancies among chemists, in estimating the equivalent of barytes.

Water at 50° F. dissolves one-twentieth of its weight of barytes, and at 212° about one-half of its weight; though M. Thenard in a table, has stated it at only one-tenth. As the solution cools, hexagonal prisms, terminated at each extremity with a four-sided pyramid, form. These crystals are often attached to one another, so as to imitate the leaves of fern. Sometimes they are deposited in cubes. They contain about 53 per cent of water, or 20 prime proportions. The supernatant liquid is barytes water. It is colourless, acrid, and caustic. It acts powerfully on the vegetable purples and yellows. Exposed to the air, it attracts carbonic acid, and the dissolved barytes is converted into carbonate, which falls down in insoluble crusts. It appears from the experiments of M. Berthollet, that heat alone cannot deprive the crystallized hydrate of its water. After exposure to a red heat, when it fuses like potash, a proportion of water remains in combination. This quantity is a prime equivalent = 1.125, to 9.7 of barytes. —The ignited hydrate is a solid of a whitish-grey colour, caustic, and very dense. It fuses at a heat a little under a cherry red; is fixed in the fire; attracts, but slowly, carbonic acid from the atmosphere. It yields carburetted hydrogen and carbonate of barytes when heated along with charcoal, provided this be not in excess.

Sulphur combines with barytes, when they are mixed together, and heated in a crucible. The same compound is more economically obtained by igniting a mixture of sulphate of barytes and charcoal in fine powder. This sulphuret is of a reddish-yellow colour, and when dry without smell. When this substance is put into hot water, a powerful action is manifested. The water is decomposed, and two new products are formed; namely, hydrosulphuret, and hydroguretted sulphuret of barytes. The first crystallizes as the liquid cools, the second remains dissolved. The hydrosulphuret is a compound of 9.7 of barytes with 2.125 sulphuretted hydrogen. Its crystals should be quickly separated by filtration, and dried by pressure between the folds of porous paper. They are white scales, have a silky lustre, are soluble in water, and yield a solution having a greenish tinge. Its taste is acrid, sulphureous, and when mixed with the hydroguretted sulphuret, eminently corrosive. It rapidly attracts oxygen from the atmosphere, and is converted into the sulphate of barytes. The hydroguretted sulphuret is a compound of 9.70 barytes with 4.125 bisulphuretted hydrogen; but contaminated with sulphite and hyposulphite in unknown proportions. The dry sulphuret consists probably of 2 sulphur + 9.7 barytes. The readiest way of obtaining barytes water is to boil the solution of the sulphuret with deutoxide of copper, which seizes the sulphur, while the hydrogen flies off, and the barytes remains dissolved.

Phosphuret of barytes may be easily formed by exposing the constituents together to heat in a glass tube. Their reciprocal action is so intense as to cause ignition. Like phosphuret of lime, it decomposes water, and causes the disengagement of phosphuretted hydrogen gas, which spontaneously inflames with contact of air. When sulphur is made to act on the deutoxide of barytes, sulphuric acid is formed, which unites to a portion of the earth into a sulphate.

The salts of barytes are white, and more or less transparent. All the soluble sulphates cause in the soluble salts of barytes, a precipitate insoluble in nitric acid. They are all poisonous except the sulphate; and hence the proper counter-poison is dilute sulphuric acid for the carbonate, and sulphate of soda for the soluble salts of barytes. An account has been given of the most useful of these salts under the respective acids. What remains of any consequence will be found in the table of SALTS. For some interesting facts on the decomposition of the sulphate and carbonate, see ATTRACTION. When the object is merely to procure barytes or the sulphuret, form the powdered carbonate or sulphate into a paste with lamp black and coal tar, and subject to strong ignition in a covered crucible.*

BARBADOES TAR. See PETROLEUM.

BARILLA, or BARILLOR. The term given in commerce to the impure soda imported from Spain and the Levant. It is made by burning to ashes different plants that grow on the sea-shore, chiefly of the genus salsola, and is brought to us in hard porous masses, of a speckled brown colour.

Kelp, a still more impure alkali made in this country by burning various sea weeds, is sometimes called *British barilla*. See SODA.

BAROLITE. Carbonate of barytes.

* BARRAS. The resinous incrustation on the wounds made in fir trees. It is also called galipot.*

BARYTES. See BARIUM.

* BASALT. Occurs in amorphous masses, columnar, amygdaloidal, and vesicular. Its colours are greyish-black, ash-grey, and raven-black. Massive. Dull lustre. Granular structure. Fracture uneven or conchoidal. Concretions, columnar, globular, or tabular. It is opaque, yields to the knife, but not easily frangible. Streak light ash-grey. Sp. grav. 3. Melts into a black glass. It is found in beds and veins in granite and mica slate, the old red sandstone, limestone, and coal formations. It is distributed over the whole world; but nowhere is met with in greater variety than in Scotland. The German basalt is supposed to be a watery deposite; and that of France to be of volcanic origin.*

The most remarkable is the columnar basaltes, which form immense masses, composed of columns thirty, forty, or more feet in height, and of enormous thickness. Nay, those at Fairhead are two hundred and fifty feet high. These constitute some of the most astonishing scenes in nature, for the immensity and regularity of their parts. The coast of Antrim in Ireland, for the space of three miles in length, exhibits a very magnificent variety of columnar cliffs; and the Giant's Causeway consists of a point of that coast formed of similar columns, and projecting into the sea, upon a descent for several hundred feet. These columns are, for the most part, hexagonal, and fit very accurately together; but most frequently not adherent to each other, though water cannot penetrate between them. And the basaltic appearances on the Hebrides Islands on the coast of Scotland, as described by Sir Joseph Banks, who visited them in 1772, are upon a scale very striking for their vastness and variety.

An extensive field of inquiry is here offered to the geological philosopher, in his attempts to ascertain the alterations to which the globe has been subjected. The inquiries of the chemist equally co-operate in these researches, and tend likewise to show to what useful purposes this and other substances may be applied. Bergmann found that the component parts of various specimens of basaltes were, at a medium 52 parts silex, 15 alumina, 8 carbonate of lime, and 25 iron. The differences seem, however, to be considerable; for Faujas de St. Fond gives these proportions: 46 silex, 30 alumina, 10 lime, 6 magnesia, and 8 iron. The amorphous basaltes, known by the name of rowley rag, the ferrilite of Kirwan, of the specific gravity of 2.748, afforded Dr. Withering 47.5 of silex, 32.5 of alumina, and 20 of iron, at a very low degree of oxidation probably. Dr. Kennedy, in his analysis of the basaltes of Staffa, gives the following as its component parts: silex 48, alumina 16, oxide of iron 16, lime 9, soda 4, muriatic acid 1, water and volatile parts 5. Klaproth gives for the analysis of the prismatic basaltes of Hasenberg: silex 44.5, alumina 16.75, oxide of iron 20, lime 9.5, magnesia 2.25, oxide of manganese 0.12, soda 2.60, water 2. On a subsequent analysis, with a view to detect the existence of muriatic acid, he found slight indications of it, but it was in an extremely minute proportion.

* Sir James Hall and Mr. Gregory Watt have both proved, by admirably conducted experiments, that basalt when fused into a perfect glass will resume the stony structure by slow cooling; and hence have endeavoured to show, that the earthy structure affords no argument against the igneous formation of basalt in the terrestrial globe.*

Basaltes, when calcined and pulverized, is said to be a good substitute for puzzolana in the composition of mortar, giving it the property of hardening under water. Wine bottles have likewise been manufactured with it, but there appears to be some nicety requisite in the management to ensure success. Mr. Castelveil, who heated his furnace with wood, added soda to the basaltes to render it more fusible; while Mr. Giral, who used pit coal, found it necessary to mix with his basaltes a very refractory sand. The best mode probably would be to choose basaltes of a close fine grain and uniform texture, and to employ it alone, taking care to regulate the heat properly; for if this be carried too high, it will drop from the iron almost like water.

* **Basaltic Hornblende.** It usually occurs in opaque six-sided single crystals, which sometimes act on the magnetic needle. It is imbedded in basalt or wacke. Colour velvet black. Lustre vitreous. Scratches glass. Sp. gr. 3.25. Fuses with difficulty into a black glass. It consists of 47 silica, 26 alumina, 8 lime, 2 magnesia, 15 iron, and 0.5 water. It is found in the basalt of Arthur's Seat, in that of Fifeshire, and in the Isles of Mull, Canna, Eigg, and Sky. It is found also in the basaltic and floetz trap-rocks of England, Ireland, Saxony, Bohemia, Silesia, Bavaria, Hungary, Spain, Italy, and France.*

* **Basanite.** See Flinty Slate.*

* **Base** or **Basis.** A chemical term usually applied to alkalis, earths, and metallic oxides, in their relations to the acids and salts. It is sometimes also applied to the particular constituents of an acid or oxide, on the supposition that the substance combined with the oxygen, &c. is the basis of the compound to which it owes its particular qualities. This notion seems unphilosophical, as these qualities depend as much on the state of combination as on the nature of the constituent.*

Bath. The heat communicated from bodies in combustion must necessarily vary according to circumstances; and this variation not only influences the results of operations, but in many instances endangers the vessels, especially if they be made of glass. Among the several methods of obviating this inconvenience, one of the most usual consists in interposing a quantity of sand, or other matter between the fire and the vessel intended to be heated. The sand bath and the water bath are most commonly used; the latter of which was called Balneum Mariæ by the elder chemists. A bath of steam may, in some instances, be found preferable to the water bath. Some chemists have proposed baths of melted lead, of tin, and of other fusible substances. These may perhaps be found advantageous in a few peculiar operations, in which the intelligent operator must indeed be left to his own sagacity.

* A considerably greater heat may be given to the water bath by dissolving various salts in it. Thus a saturated solution of common salt boils at 225°.3, or 13°.3 Fahr. above the boiling point of water. By using solution of muriate of lime, a bath of any temperature from 212 to 252° may be conveniently obtained.*

Bdellium. A gum resin, supposed to be of African origin. The best bdellium is of a yellowish brown, or dark brown colour, according to its age; unctuous to the touch, brittle, but soon softening, and growing tough betwixt the fingers; in some degree transparent, not unlike myrrh; of a bitterish taste, and a moderately strong smell. It does not easily take flame, and, when set on fire, soon goes out. In burning it sputters a little, owing to its aqueous humidity. * Its sp. grav. is 1.371. Alcohol dissolves about three-fifths of bdellium, leaving a mixture of gum and cerasin. Its constituents, according to Pelletier, are 59 resin, 9.2 gum, 30.6 cerasin, 1.2 volatile oil and loss.*

* **Bean.** The seed of the *vicia faba*, a small esculent bean, which becomes black as it ripens, has been analyzed by Einholf. He found 3840 parts to consist of 600 volatile matter, 386 skins, 610 fibrous starchy matter, 1312 starch, 417 vegeto-animal matter, 31 albumen, 136 extractive, soluble in alcohol, 177 gummy matter, 37½ earthy phosphate, 133½ loss. Fourcroy and Vauquelin found its incinerated ashes to contain the phosphates of lime, magnesia, potash, and iron, with uncombined potash. They found no sugar in this bean. Kidney beans, the seeds of the *phaseolus vulgaris*, yielded to Einholf 288 skins, 425 fibrous starchy matter, 1380 starch, 799 vegeto-animal matter, not quite free from starch, 131 extractive, 52 albumen, with some vegeto-animal matter, 744 mucilage, and 21 loss in 3840.*

* **Bee.** The venom of the bee according to Fontana, bears a close resemblance to that of the viper. It is contained in a small vesicle, and has a hot and acrid taste, like that of the scorpion.*

Beer is the wine of grain. Malt is usually made of barley. The grain is steeped for two or three days in water until it swells, becomes somewhat tender, and tinges the water of a bright reddish-brown color. The water being then drained away, the barley is spread about two feet thick upon a floor, where it heats spontaneously, and begins to grow, by first shooting out the radicle. In this state the germination is stopped by spreading it thinner, and turning it over for two days;† after which it is again made into a heap, and suffered to become sensibly hot, which usually happens in little more than a day. Lastly, it is conveyed to the kiln, where, by a gradual and low heat, it is rendered dry and crisp. This is malt; and its qualities differ according as it is more or less soaked, drained, germinated, dried, and baked. In this, as in other manufactories, the intelligent operators often make a mystery of their processes from views of profit; and others pretend to peculiar secrets who really possess none.

Indian corn, and probably all large grain, requires to be suffered to grow into the blade, as well as root, before it is fit to be made into malt. For this purpose it is buried about two or three inches deep in the ground, and covered with loose earth; and in ten or twelve days it springs up. In this state it is taken up and washed, or fanned, to clear it from its dirt; and then dried in the kiln for use.

* Barley, by being converted into malt, becomes one-fifth lighter, or 20 per cent; 12 of which are owing to kiln drying, 1.5 are carried off by the steep-water, 3 dissipated on the floor, 3 lost in cleaning the roots, and 0.5 waste or loss.*

The degree of heat to which the malt is exposed in this process, gradually changes its colour from very pale to actual blackness, as it simply dries it, or converts it to charcoal.

The colour of the malt not only affects the colour of the liquor brewed from it; but, in consequence of the chemical operation, of the heat applied, on the principles that are developed in the grain during the process of malting, materially alters the quality of the beer, especially with regard to the properties of becoming fit for drinking and growing fine.

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†The time varies very much with the weather, and is never so short as two days. The perfection of the process is judged of, by the length of the roots and the germ; of the latter especially. When this has passed two-thirds of the length of the grain, it is time to check the vegetation. Heaping it up is unnecessary. If allowed to lie in heaps so long as to heat much, the malt would be injured. The drying cannot be well effected by heat in a close vessel. A current of dry air is the desideratum. I have seen malt made by dry air at the heat of 90 degrees. Our summer sun would answer. Greater heat gives more colour and stronger flavour, but less strength to the wort. Neither Indian corn nor rice are improved by malting, for the purpose of fermentation. Those grains only are improved by it, which have the germ to pass internally from one end to the other before coming out. One-third raw Indian corn meal, ground up with two-thirds malt, gives more strength than all malt.

Beer is made from malt previously ground, or cut to pieces by a mill. This is placed in a tun, or tub with a false bottom; hot water is poured upon it, and the whole stirred about with a proper instrument. The temperature of the water in this operation, called Mashing, must not be equal to boiling; for, in that case, the malt would be converted into a paste, from which the impregnated water could not be separated. This is called Setting.[†1] After the infusion has remained for some time upon the malt, it is drawn off, and is then distinguished by the name of Sweet Wort. By one or more subsequent infusions of water, a quantity of weaker wort is made, which is either added to the foregoing, or kept apart, according to the intention of the operator. The wort is then boiled with hops, which gives it an aromatic bitter taste, and is supposed[†2] to render it less liable to be spoiled in keeping; after which it is cooled in shallow vessels, and suffered to ferment,[†3] with the addition of a proper quantity of yeast. The fermented liquor is beer; and differs greatly in its quality, according to the nature of the grain, the malting, the mashing, the quantity and kind of the hops and the yeast, the purity or admixtures of the water made use of, the temperature and vicissitudes of the weather, &c.

Beside the various qualities of malt liquors of a similar kind, there are certain leading features by which they are distinguished, and classed under different names, and to produce which, different modes of management must be pursued. The principal distinctions are into beer, properly so called; ale; table or small beer; and porter, which is commonly termed beer in London. Beer is a strong, fine, and thin liquor; the greater part of the mucilage having been separated by boiling the wort longer than for ale, and carrying the fermentation farther, so as to convert the saccharine matter into alcohol. Ale is of a more sirupy consistence, and sweeter taste; more of the mucilage being retained in it, and the fermentation not having been carried so far as to decompose all the sugar.[†] Small beer, as its name implies, is a weaker liquor; and is made, either by adding a large portion of water to the malt, or by mashing with a fresh quantity of water what is left after the beer or ale wort is drawn off. Porter was probably made originally from very high dried malt; but it is said, that its peculiar flavour cannot be imparted by malt and hops alone.

Mr. Brande obtained the following quantities of alcohol from 100 parts of different species of beers. Burton ale, 8.88, Edinburgh ale, 6.2, Dorchester ale, 5.56; the average being = 6.87. Brown stout, 6.8, London porter (average) 4.2, London small beer, (average) 1.28.

As long ago as the reign of Queen Anne, brewers were forbid to mix sugar, honey, Guinea pepper, essentia bina, cocculus indicus, or any other unwholesome ingredient, in beer, under a certain penalty; from which we may infer, that such at least was the practice of some; and writers, who profess to discuss the secrets of the trade, mention most of these and some other articles as essentially necessary. The essentia bina is sugar boiled down to a dark colour, and empyreumatic flavour. Broom tops, wormwood, and other bitter plants, were formerly used to render beer fit for keeping, before hops were introduced into this country; but now are prohibited to be used in beer made for sale.

[†1] The temperature should never be above 180 degrees of Fahrenheit.

[†2] It is well known, that other things being equal, the liquor keeps in proportion to the quantity of hops. Fresh beer may have from a pound to a pound and a half to a barrel of 32 gallons. June beer, two pounds and a half: beer for the month of August, three pounds; and for a second summer, three and an half. For India voyages, four pounds.

[†3] It ought not to ferment in shallow vessels, but in vessels of a cubical or deep cylindrical form. The fermentation should be commenced not lower than fifty-eight nor higher than sixty-six F. The smaller the fermenting tun and the colder the weather, the warmer the wort should be, and vice versa. The fall of the head resulting from the loss of the viscidity, which enables it to confine the carbonic acid, is the most obvious mark to determine when the fermentation should stop. The hydrometer or saccharometer affords a better mean of judging, since the same degree of attenuation takes place in all infusions over a certain strength, or 22 lbs. to the London barrel, according to instruments made in that city. From 15 to 17 pounds to the barrel of diminution will generally be observed. The fermentation is then to be stopped, by allowing the liquor to run into smaller vessels of about sixty gallons, and in these it becomes depurated by the yeast, which, evolved by the fermentation, entangles the carbonic acid, and is brought to the top of the beer by it, so as to roll out at the bung: this is called cleansing.

[†] There is no essential difference between the mode of brewing ale and beer. The colour and flavour of the malt is the principal ground of distinction. Keeping ale is boiled longer than fresh beer. The more sirupy consistence is in consequence of more malt being used.

* By the present law of this country, nothing is allowed to enter into the composition of beer, except malt and hops. Quassia and wormwood are often fraudulently introduced; both of which are easily discoverable by their nauseous bitter taste. They form a beer which does not preserve so well as hop beer. Sulphate of iron, alum, and salt, are often added by the publicans, under the name of *beer-heading*, to impart a frothing property to beer, when it is poured out of one vessel into another. Molasses and extract of gentian root are added with the same view. Capsicum, grains of paradise, ginger root, coriander seed, and orange peel, are also employed to give pungency and flavour to weak or bad beer. The following is a list of some of the unlawful substances seized at different breweries, and brewers' druggists' laboratories, in London, as copied from the minutes of the committee of the House of Commons. Coculus indicus, multum, (an extract of the cocculus), colouring, honey, hartshorn shavings, Spanish juice, orange powder, ginger, grains of paradise, quassia, liquorice, caraway seeds, copperas, capsicum, mixed drugs. Sulphuric acid is very frequently added to *bring beer forward*, or make it hard, giving new beer instantly the taste of what is 18 months old. According to Mr. Accum, the present *entire* beer of the London brewer is composed of all the waste and spoiled beer of the publicans, the bottoms of butts, the leavings of the pots, the drippings of the machines for drawing the beer, the remnants of beer that lay in the leaden pipes of the brewery, with a portion of brown stout, bottling beer, and mild beer. He says that opium, tobacco, nux vomica, and extract of poppies, have likewise been used to adulterate beer. For an account of the poisonous qualities of the *cocculus indicus*, see Picrotoxia, and for those of nux vomica, see Strychnia. By evaporating a portion of beer to dryness, and igniting the residuum with chlorate of potash, the iron of the copperas will be procured in an insoluble oxide. Muriate of barytes will throw down an abundant precipitate from beer contaminated with sulphuric acid or copperas, which precipitate may be collected, dried, and ignited. It will be insoluble in nitric acid.*

Beer appears to have been of ancient use, as Tacitus mentions it among the Germans, and has been usually supposed to have been peculiar to the northern nations: but the ancient Egyptians, whose country was not adapted to the culture of the grape, had also contrived this substitute for wine; and Mr. Park has found the art of making malt, and brewing from it very good beer, among the negroes in the interior parts of Africa.

Beet. The root of the beet affords a considerable quantity of sugar, and has lately been cultivated for the purpose of extracting it to some extent in Germany. See Sugar. It is likewise said, that if beet roots be dried in the same manner as malt, after the greater part of their juice is pressed out, very good beer may be made from them.

* **Bellmetal.** See Copper.*

* **Bellmetal Ore.** See Ores of Tin.*

Ben (Oil of). This is obtained from the ben nut, by simple pressure. It is remarkable for its not growing rancid in keeping, or at least not until it has stood for a number of years; and on this account it is used in extracting the aromatic principle of such odoriferous flowers as yield little or no essential oil in distillation.

* **Benzoic Acid.** See Acid (Benzoic).*

Benzoin or Benjamin. The tree which produces Benzoin is a native of the East Indies, particularly of the island Siam and Sumatra.§ The juice exudes from incisions, in the form of a thick white balsam. If collected as soon as it has grown somewhat solid, it proves internally white like almond, and hence it is called Benzoë Amygdaloides; if suffered to lie long exposed to the sun and air, it changes more and more to a brownish, and at last to a quite reddish-brown colour.

This resin is moderately hard and brittle, and yields an agreeable smell when rubbed or warmed. When chewed, it impresses a slight sweetness on the palate. It is totally soluble in alcohol; from which, like other resins, it may be precipitated by the addition of water. Its specific gravity is 1.092.

The white opaque fluid thus obtained has been called Lac Virginale; and is still sold, with other fragrant additions, by perfumers, as a cosmetic. Boiling water separates the peculiar acid of benzoin.

The products Mr. Brande obtained by distillation were, from a hundred grains, benzoic acid 9 grains, acidulated water 5.5, butyraceous and empyreumatic oil 60, brittle coal 22, and a mixture of carburetted hydrogen and carbonic acid gas, computed at 3.5. On treating the empyreumatic oil with water, however, 5 grains more of acid were extracted, making 14 in the whole.

* From 1500 grains of benzoin, Bucholz

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§Consult the Philosophical Transactions, vol. lxxvii. page 307, for a botanical description and drawing of the tree, by Dryander.

obtained 1250 of resin, 187 benzoic acid, 25 of a substance similar to balsam of Peru, 8 of an aromatic substance soluble in water and alcohol, and 30 of woody fibres and impurities.

Ether, sulphuric and acetic acids, dissolve benzoin; so do solutions of potash and soda. Nitric acid acts violently on it, and a portion of artificial tannin is formed. Ammonia dissolves it sparingly.*

* **Bergmannite.** A massive mineral of a greenish, greyish-white, or reddish colour. Lustre intermediate between pearly and resinous. Fracture fibrous, passing into fine grained, uneven. Slightly translucent on the edges. Scratches felspar. Fuses into a transparent glass, or a semi-transparent enamel. It is found at Fredrickswarn in Norway, in quartz and in felspar.*

* **Beryl.** This precious mineral† is most commonly green, of various shades, passing into honey-yellow, and sky-blue. It is crystallized in hexahedral prisms deeply striated longitudinally, or in 6 or 12 sided prisms, terminated by a 6 sided pyramid, whose summit is replaced. It is harder than the emerald, but more readily yields to cleavage. Its sp. grav. is 2.7. Its lustre is vitreous. It is transparent, and sometimes only translucent. It consists by Vauquelin of 68 silica, 15 alumina, 14 glucina, 1 oxide of iron, 2 lime. Berzelius found in it a trace of oxide of tantalum. It occurs in veins traversing granite in Daouria; in the Altaic chain in Siberia; near Limoges in France; in Saxony; Brazil; at Kinloch Raimoch, and Cairngorm, Aberdeenshire, Scotland; above Dundrum, in the county of Dublin, and near Cronebane, county of Wicklow, in Ireland. It differs from emerald in hardness and colour. It has been called aqua marine, and greenish-yellow emerald. It is electric by friction and not by heat.*

* **Bezoar.** This name, which is derived from a Persian word implying an antidote to poison, was given to a concretion found in the stomach of an animal of the goat kind, which was once very highly valued for this imaginary quality, and has thence been extended to all concretions found in animals.

These are of eight kinds, according to Fourcroy, Vauquelin, and Berthollet. 1. Superphosphate of lime, which forms concretions in the intestines of many *mammalia*. 2. Phosphate of magnesia, semi-transparent and yellowish, and of sp. grav. 2.160. 3. Phosphate of ammonia and magnesia. A concretion of a grey or brown colour, composed of radiations from a centre. It is found in the intestines of herbiverous animals, the elephant, horse, &c. 4. Biliary, colour reddish-brown, found frequently in the intestines and gall bladder of oxen, and used by painters for an orange-yellow pigment. It is inspissated bile. 5. Resinous. The oriental bezoars, procured from unknown animals, belong to this class of concretions. They consist of concentric layers, are fusible, combustible, smooth, soft, and finely polished. They are composed of bile and resin. 6. Fungous, consisting of pieces of the boletus igniarius, swallowed by the animal. 7. Hairy. 8. Ligniform. Three bezoars sent to Bonaparte by the king of Persia, were found by Berthollet to be nothing but woody fibre agglomerated.*

Bihydroguret of Carbon. See **Carburetted Hydrogen.**

Bihydroguret of Phosphorus. See **Phosphuretted Hydrogen.**

* **Bildstein, Agalmatolite,** or **Figurestone.** A massive mineral, with sometimes an imperfectly slaty structure. Colour gray, brown, flesh red, and sometimes spotted, or with blue veins. It is translucent on the edges, unctuous to the touch, and yields to the nail. Sp. grav. 2.8. It is composed of 56 silica, 29 alumina, 7 potash, 2 lime, 1 oxide of iron, and 5 water, by Vauquelin. Klaproth found in a specimen from China, 54.5 silica, 34 alumina, 6.25 potash, 0.75 oxide of iron, and 4 water. It fuses into a transparent glass. M. Brongniart calls it *steatite pagodite*, from its coming from China cut into grotesque figures. It wants the magnesia, which is a constant ingredient of steatites. It is found at Naygag in Transylvania, and Glyder-bach in Wales.

* **Bile.** A bitter liquid, of a yellowish or greenish-yellow colour, more or less viscid, of a sp. gravity greater than that of water, common to a great number of animals, the peculiar secretion of their liver. It is the prevailing opinion of physiologists, that the bile is separated from the venous, and not like the other secretions, from the arterial blood. The veins which receive the blood distributed to the abdominal viscera, unite into a large trunk called the *vena portæ*, which divides into two branches, that penetrate into the liver, and divide into innumerable ramifications. The last of these terminate partly in the biliary ducts, and partly in the hepatic veins, which restore to the circulation the blood not needed for the formation of bile. This liquid passes directly into the duodenum by the *ductus choledochus*, when the animal has no gall bladder; but when it has one, as more frequently happens, the bile flows back into it by the cystic duct, and remaining there for a longer or shorter time, experiences remarkable alterations. Its principal use seems to be, to promote the duodenal digestion, in concert with the pancreatic juice.

Boerhaave, by an extravagant error, regarded the bile as one of the most putrescible fluids; and hence originated many hypothetical and absurd theories on diseases and their treatment. We shall follow the arrangement of M. Thenard, in a subject which owes to him its chief illustration.

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† Beryl is not always precious, and even when transparent, as in the form of aqua marina, has little value.

1. Ox bile is usually of a greenish-yellow colour, rarely a deep green. By its colour it changes the blue of turnsole and violet to a reddish-yellow. At once very bitter, and slightly sweet, its taste is scarcely supportable. Its smell, though feeble, is easy to recognize, and approaches somewhat to the nauseous odour of certain fatty matters when they are heated. Its specific gravity varies very little. It is about 1.026 at 43° F. It is sometimes limpid, and at others disturbed with a yellow matter, from which it may be easily separated by water; its consistence varies from that of a thin mucilage, to viscidity. Cadet regarded it as a kind of soap. This opinion was first refuted by M. Thenard. According to this able chemist, 800 parts of ox bile, are composed of 700 water, 15 resinous matter, 69 picromel, about 4 of a yellow matter, 4 of soda, 2 phosphate of soda, 3.5 muriates of soda and potash, 0.8 sulphate of soda, 1.2 phosphate of lime, and a trace of oxide of iron. When distilled to dryness, it leaves from 1-8th to 8.9th of solid matter, which, urged with a higher heat, is resolved into the usual igneous products of animal analysis; only with more oil and less carbonate of ammonia.

Exposed for some time in an open vessel, the bile gradually corrupts and lets fall a small quantity of a yellowish matter; then its mucilage decomposes. Thus the putrefactive process is very inactive, and the odour it exhales is not insupportable, but in some cases has been thought to resemble that of musk. Water and alcohol combine in all proportions with bile. When a very little acid is poured into bile, it becomes slightly turbid, and reddens litmus; when more is added, the precipitate augments, particularly if sulphuric acid be employed. It is formed of a yellow animal matter, with very little resin. Potash and soda increase the thinness and transparency of bile. Acetate of lead precipitates the yellow matter and the sulphuric and phosphoric acids of the bile. The solution of the subacetate precipitates not only these bodies, but also the picromel and the muriatic acid, all combined with the oxide of lead. The acetic acid remains in the liquid united to the soda. The greater number of fatty substances are capable of being dissolved by bile. This property, which made it be considered a soap, is owing to the soda, and to the triple compound of soda, resin, and picromel. Scourers sometimes prefer it to soap, for cleansing woollen. The bile of the calf, the dog, and the sheep, is similar to that of the ox. The bile of the sow contains no picromel. It is merely a soda-resinous soap. Human bile is peculiar. It varies in colour, sometimes being green, generally yellowish-brown, occasionally almost colourless. Its taste is not very bitter. In the gall bladder it is seldom limpid, containing often, like that of the ox, a certain quantity of yellow matter in suspension. At times this is in such quantity, as to render the bile somewhat grumous. Filtered and boiled, it becomes very turbid, and diffuses the odour of white of egg. When evaporated to dryness, there results a brown extract, equal in weight to 1-11th of the bile. By calcination we obtain the same salts as from ox bile.

All the acids decompose human bile, and occasion an abundant precipitate of albumen and resin, which are easily separable by alcohol. One part of nitric acid, sp. grav. 1.210, saturates 100 of bile. On pouring into it a solution of sugar of lead, it is changed into a liquid of a light yellow colour, in which no picromel can be found, and which contains only acetate of soda, and some traces of animal matter. Human bile appears hence to be formed, by Thenard, in 1100 parts; of 1000 water; from 2 to 10 yellow insoluble matter; 42 albumen; 41 resin; 5.6 soda: and 45 phosphates of soda and lime, sulphate of soda, muriate of soda and oxide of iron. But by Berzelius, its constituents are in 1000 parts: 908.4 water; 80 picromel; 3 albumen; 4.1 soda; 0.1 phosphate of lime; 3.4 common salt, and 1. phosphate of soda, with some phosphate of lime.*

Birdlime. The best birdlime is made of the middle bark of the holly, boiled seven or eight hours in water, till it is soft and tender; then laid in heaps in pits in the ground and covered with stones, the water being previously drained from it; and in this state left for two or three weeks to ferment till it is reduced to a kind of mucilage. This being taken from the pit is pounded in a mortar to a paste, washed in river water, and kneaded, till it is freed from extraneous matters. In this state it is left four or five days in earthen vessels, to ferment and purify itself, when it is fit for use.

It may likewise be obtained from the misleto, the viburnum lantana, young shoots of elder, and other vegetable substances.

It is sometimes adulterated with turpentine, oil, vinegar, and other matters.

Good birdlime is of a greenish colour and sour flavour; gluey, stringy, and tenacious; and in smell resembling linseed oil. By exposure to the air it becomes dry and brittle, so that it may be powdered; but its viscidity is restored by wetting it. It reddens tincture of litmus. Exposed to a gentle heat it liquefies slightly, swells in bubbles, becomes grumous, emits a smell resembling that of animal oils, grows brown, but recovers its properties on cooling, if not heated too much.. With a greater heat it burns, giving out a brisk flame and much smoke. The residuum contains sulphate and muriate of potash, carbonate of lime and alumina, with a small portion of iron.

Bismuth is a metal of a yellowish or reddish-white colour, little subject to change in the air.† It is somewhat harder than lead, and is scarely, if at all, malleable; being easily broken, and even reduced to powder, by the hammer. The internal face, or place of fracture, exhibits large shining plates, disposed in a variety of positions; thin pieces are considerably sonorous. At a temperature of 480° Fahrenheit, it melts; and its surface becomes covered with a greenish-grey, or brown oxide. A stronger heat ignites it, and causes it to burn with a small blue flame; at the same time that a yellowish oxide, known by the name of flowers of bismuth, is driven up. This oxide appears to rise in consequence of the combustion; for it is very fixed, and runs into a greenish glass when exposed to heat alone.

* This oxide consists of 100 metal + 11.275 oxygen, whence its prime equivalent will be 9.87, and that of the metal itself 8.87. The specific gravity of the metal is 9.85.*

Bismuth, urged by a strong heat in a closed vessel, sublimes entire, and crystallizes very distinctly when gradually cooled.

The sulphuric acid has a slight action upon bismuth, when it is concentrated and boiling. Sulphurous acid gas is exhaled, and part of the bismuth is converted into a white oxide. A small portion combines with the sulphuric acid, and affords a deliquescent salt in the form of small needles.

The nitric acid dissolves bismuth with the greatest rapidity and violence; at the same time that much heat is extricated, and a large quantity of nitric oxide escapes. The solution, when saturated, affords crystals as it cools; the salt detonates weakly, and leaves a yellow oxide behind, which effloresces in the air. Upon dissolving this salt in water, it renders that fluid of a milky white, and lets fall an oxide of the same colour.

The nitric solution of bismuth exhibits the same property when diluted with water, most of the metal falling down in the form of a white oxide, called magistery of bismuth. This precipitation of the nitric solution, by the addition of water, is the criterion by which bismuth is distinguished from most other metals. The magistery or oxide is a very white and subtile powder: when prepared by the addition of a large quantity of water, it is used as a paint for the complexion, and is thought gradually to impair the skin. The liberal use of any paint for the skin seems indeed likely to do this; but there is reason to suspect, from the resemblance between the general properties of lead and bismuth, that the oxide of this metal may be attended with effects similar to those which the oxides of lead are known to produce. If a small portion of muriatic acid be mixed with the nitric, and the precipitated oxide be washed with but a small quantity of cold water, it will appear in minute scales of a pearly lustre, constituting the *pearl powder* of perfumers. These paints are liable to be turned black by sulphuretted hydrogen gas.

The muriatic acid does not readily act upon bismuth.

* When bismuth is exposed to chlorine gas it takes fire, and is converted into a chloride, which, formerly prepared by heating the metal with corrosive sublimate, was called butter of bismuth. The chloride is of a grayish-white colour, a granular texture, and is opaque. It is fixed at a red heat. According to Dr. John Davy, it is composed of 33.6 chlorine, + 66.4 bismuth, = 100; or in equivalent numbers, of 4.45 chlorine, + 8.87 bismuth, = 13.32. When iodine and bismuth are heated together, they readily form an iodide of an orange-yellow colour, insoluble in water, but easily dissolved in potash ley.*

Alkalis likewise precipitate its oxide; but not of so beautiful a white colour as that afforded by the affusion of pure water.

The gallic acid precipitates bismuth of a greenish-yellow, as ferroprussiate of potash does of a yellowish colour.

* There appears to be two sulphurets, the first a compound of 100 bismuth to 22.34 sulphur; the second of 100 to 46.5; the second is a bisulphuret.*

This metal unites with most metallic substances, and renders them in general more fusible. When calcined with the imperfect metals, its glass dissolves them, and produces the same effect as lead in cupellation; in which process it is even said to be preferable to lead.

Bismuth is used in the composition of pewter, in the fabrication of printers' types, and in various other metallic mixtures. With an equal weight of lead, it forms a brilliant white alloy, much harder than lead, and more malleable than bismuth, though not ductile; and if the proportion of lead be increased, it is rendered still more malleable. Eight parts of bismuth, five of lead, and three of tin, constitute the fusible metal, sometimes called Newton's; from its discoverer, which melts at the heat of boiling water, and may be fused over a candle in a piece of stiff paper without burning the paper. One part of bismuth, with five of lead, and three of tin, forms plumbers' solder. It forms the basis of a sympathetic ink. The oxide of bismuth, precipitated by potash from nitric acid, has been recommended in spasmodic disorders of the stomach, and given in doses of four grains four times a day. A writer in the Jena Journal says he has known the dose carried gradually to one scruple without injury.

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† It is more properly tin or silver-white with a blush of red.

Bismuth is easily separable, in the dry way, from its ores, on account of its great fusibility. It is usual, in the processes at large, to throw the bismuth ore into a fire of wood; beneath which a hole is made in the ground to receive the metal, and defend it from oxidation. The same process may be imitated in the small way, in the examination of the ores of this metal; nothing more being necessary, than to expose it to a moderate heat in a crucible, with a quantity of reducing flux; taking care, at the same time, to perform the operation as speedily as possible, that the bismuth may be neither oxidized nor volatilized.

Bistre. A brown pigment, consisting of the finer parts of wood soot, separated from the grosser by washing. The soot of the beech is said to make the best.

* **Bitter Principle**, of which there are several varieties.

When nitric acid is digested on silk, indigo, or white willow, a substance of a deep yellow colour, and an intensely bitter taste, is formed. It dyes a permanent yellow. It crystallizes, in oblong plates, and saturates alkalis, like an acid, producing crystallizable salts. That with potash, is in yellow prisms. They are bitter, permanent in the air, and less soluble than the insulated bitter principle. On hot charcoal they deflagrate. When struck smartly on an anvil, they detonate with much violence, and with emission of a purple light. Ammonia deepens the colour of the bitter principle solution, and forms a salt in yellow spiculæ. It unites also with the alkaline earths and metallic oxides. M. Chevreul considers it a compound of nitric acid, with a peculiar substance of an oily nature. Quassia, cocculus Indicus, daphne Alpina, coffee, squills, colocynth, and bryony, as well as many other medicinal plants, yield bitter principles, peculiarly modified.*

Bittern. The mother water which remains after the crystallization of common salt in sea water, or the water of salt springs. It abounds with sulphate and muriate of magnesia, to which its bitterness is owing. See Water (Sea).

* **Bitterspar, or Rhombspar.** This mineral crystallizes in rhomboids, which were confounded with those of calcareous spar, till Dr. Wollaston applied his admirable reflecting goniometer, and proved the peculiarity of the angles in bitterspar, which are 106° 15′, and 73° 45′. Its colour is grayish or yellow, with a somewhat pearly lustre. It is brittle, semi-transparent, splendent, and harder than calcareous spar. Fracture straight foliated with a threefold cleavage. Its sp. gr. is 2.88. It consists of from 68 to 73 carbonate of lime, 25 carbonate of magnesia, and 2 oxide of manganese. It is usually imbedded in serpentine, chlorite or steatite; and is found in the Tyrol, Salzburg, and Dauphiny. In Scotland, on the borders of Loch Lomond in the chlorite slate, and near Newton-Stewart in Galloway; as also in the Isle of Mann. It bears the same relation to dolomite and magnesian limestone, that calcareous spar does to common limestone.*

Bitumen. This term includes a considerable range of inflammable mineral substances, burning with flame in the open air. They are of different consistency, from a thin fluid to a solid; but the solids are for the most part liquefiable at a moderate heat. The fluid are, 1. Naphtha; a fine, white, thin, fragrant, colourless oil, which issues out of white, yellow, or black clays in Persia and Media. This is highly inflammable, and is decomposed by distillation. It dissolves resins, and the essential oils of thyme and lavender; but is not itself soluble either in alcohol or ether. It is the lightest of all the dense fluids, its specific gravity being 0.708. 2. Petroleum, which is a yellow, reddish, brown, greenish, or blackish oil, found dropping from rocks, or issuing from the earth, in the duchy of Modena, and in various other parts of Europe and Asia. This likewise is insoluble in alcohol, and seems to consist of naphtha, thickened by exposure to the atmosphere. It contains a portion of the succinic acid. 3. Barbadoes tar, which is a viscid, brown, or black inflammable substance, insoluble in alcohol, and containing the succinic acid. This appears to be the mineral oil in its third state of alteration. The solid are, 1. Asphaltum, mineral pitch, of which there are three varieties: the cohesive; the semi-compact, maltha; the compact, or asphaltum. These are smooth, more or less hard or brittle, inflammable substances, which melt easily, and burn without leaving any or but little ashes, if they be pure. They are slightly and partially acted on by alcohol and ether. 2. Mineral tallow, which is a white substance of the consistence of tallow, and as greasy, although more brittle. It was found in the sea on the coasts of Finland, in the year 1736; and is also met with in some rocky parts of Persia. It is nearly one-fifth lighter than tallow; burns with a blue flame, and a smell of grease, leaving a black viscid matter behind, which is more difficultly consumed. 3. Elastic bitumen, or mineral caoutchouc, of which there are two varieties. Beside these, there are other bituminous substances, as jet and amber, which approach the harder bitumens in their nature; and all the varieties of pit-coal, and the bituminous schistus, or shale, which contain more or less of bitumen in their composition. See the different kinds of bitumen and bituminous substances, in their respective places in the order of the alphabet.

† There are no two substances more opposite in their habitudes with caloric, than carbon and hydrogen. The last is, of all ponderable substances, the most volatile; and, per se, probably the most incondensible. Charcoal, on the other hand, cannot even be fused, much less volatilized, per se. It has, perhaps, of all substances, the least disposition to combine with caloric. Hence, in the combinations of hydrogen and carbon, we find a gradation of properties from substances, fixed like anthracite, to naphtha, or inflammable matter, almost as volatile as air, accordingly as the carbon or hydrogen predominates in the compound.

The distillation of rosin yields, besides carburetted hydrogen, a species of petroleum; and this by rectification yields an essential oil, like oil of tar, and afterwards some heavier and less volatile products, some of which though white at first turn black by keeping.

In like manner, mineral bitumens and bituminous coals yield petroleum, and volatile oil. A quantity of acetic acid comes over in combination with the petroleum of rosin, and is retained till the heat is considerable. It is then evolved with explosive violence.†

* **Bituminous Limestone** is of a lamellar structure; susceptible of polishing; emits an unpleasant smell when rubbed, and has a brown or black colour. Heat converts it into quicklime. It contains 8.8 alumina; 0.6 silica; 0.6 bitumen; and 89.75 carbonate of lime. It is found near Bristol, and in Galway in Ireland. The Dalmatian is so charged with bitumen that it may be cut like soap, and is used for building houses. When the walls are reared, fire is applied to them and they burn white.*

* **Black Chalk.** This mineral has a bluish-black colour; a slaty texture; soils the fingers, and is meagre to the touch. It contains about 64 silica, 11 alumina, 11 carbon, with a little iron and water. It is found in primitive mountains, and also sometimes near coal formations. It occurs in Caernarvonshire, and in the Island of Isla.*

Black Jack. The miners distinguish blende, or mock lead, by this name. It is an ore of zinc.

Black Lead. See **Plumbago.**

Black Wadd. One of the ores of manganese.

* **Bleaching.** The chemical art by which the various articles used for clothing are deprived of their natural dark colour and rendered white.

The colouring principle of silk is undoubtedly resinous. Hence, M. Baumé proposed the following process, as the best mode of bleaching it. On six pounds of yellow raw silk, disposed in an earthen pot, 48 pounds of alcohol, sp. gr. 0.867, mixed with 12 oz. muriatic acid, sp. gr. 1.100, are to be poured. After a day's digestion, the liquid passes from a fine green colour to a dusky brown. The silk is then to be drained, and washed with alcohol. A second infusion with the above acidulated alcohol is then made, for four or six days, after which the silk is drained and washed with alcohol. The spirit may be recovered by saturating the mingled acid with alkali or lime, and distilling. M. Baumé says, that silk may thus be made to rival or surpass in whiteness and lustre, the finest specimens from Nankin. But the ordinary method of bleaching silk is the following:*—The silk, being still raw, is put into a bag of thin linen, and thrown into a vessel of boiling river water, in which has been dissolved good Genoa or Toulon soap.

After the silk has boiled two or three hours in that water, the bag being frequently turned, it is taken out to be beaten, and is then washed in cold water. When it has been thus thorougly washed and beaten, they wring it slightly, and put it for the second time into the boiling vessel, filled with cold water, mixed with soap and a little indigo; which gives it that bluish cast commonly observed in white silk.

When the silk is taken out of this second water, they wring it hard with a wooden peg, to press out all the water and soap; after which they shake it to untwist it, and separate the threads. Then they suspend it in a kind of stove constructed for that purpose, where they burn sulphur; the vapour of which gives the last degree of whiteness to the silk.

The method of bleaching woollen stuffs.—There are three ways of doing this. The first is with water and soap; the second with the vapour of sulphur; and the third with chalk, indigo, and the vapour of sulphur.

Bleaching with soap and water.—After the stuffs are taken out of the fuller's mill, they are put into soap and water, a little warm, in which they are again worked by the strength of the arms over a wooden bench: this finishes giving them the whitening which the fuller's mill had only begun. When they have been sufficiently worked with the hands, they are washed in clear water and put to dry.

This method of bleaching woollen stuffs is called the Natural Method.

Bleaching with sulphur.——They begin with washing and cleansing the stuffs thoroughly in river water; then they put them to dry upon poles or perches. When they are half dry, they stretch them out in a very close stove, in which they burn sulphur; the vapour of which diffusing itself, adheres by degrees to the whole stuff, and gives it a fine whitening; this is commonly called Bleaching by the Flower, or Bleaching of Paris, because they use this method in that city more than any where else.

* The colouring matter of linen and cotton is also probably resinous; at least the experiments of Mr. Kirwan on alkaline lixivia saturated with the dark colouring matter, lead to that conclusion. By neutralizing the alkali with dilute muriatic acid, a precipitate resembling lac was obtained, soluble in alcohol, in solutions of alkalis, and alkaline sulphurets.

The first step towards freeing vegetable yarn or cloth from their native colour, is fermentation. The raw goods are put into a large wooden tub, with a quantity of used alkaline lixivium, in an acescent state, heated to about the hundredth degree of Fahr. It would be better to use some uncoloured fermentable matter, such as soured bran or potato paste, along with *clean* warm water. In a short time, an intestine motion arises, air bubbles escape, and the goods swell, raising up the loaded board which is used to press them into the liquor. At the end of from 18 to 48 hours, according to the quality of the stuffs, the fermentation ceases, when the goods are to be immediately withdrawn and washed. Much advantage may be derived by the skilful bleacher, from conducting the acetous fermentation completely to a close, without incurring the risk of injuring the fibre, by the putrefactive fermentation.

The goods are next exposed to the action of hot alkaline lixivia, by bucking or boiling, or both. The former operation consists in pouring boiling hot ley on the cloth placed in a tub; after a short time drawing off the cool liquid below, and replacing it above, by hot lixivium. The most convenient arrangement of apparatus is the following:—Into the mouth of an egg-shaped iron boiler, the bottom of a large tub is fixed air tight. The tub is furnished with a false bottom pierced with holes, a few inches above the real bottom. In the latter, a valve is placed, opening downwards, but which may be readily closed, by the upwards pressure of steam. From the side of the iron boiler, a little above its bottom, a pipe issues, which, turning at right angles upwards, rises parallel to the outside of the bucking tub, to a foot or two above its summit. The vertical part of this pipe forms the cylinder of a sucking pump, and has a piston and rod adapted to it. At a few inches above the level of the mouth of the tub, the vertical pipe sends off a lateral branch, which terminates in a bent-down nozzle, over a hole in the centre of the lid of the tub. Under the nozzle and immediately within the lid, is a metallic circular disc. The boiler being charged with lixivium, and the tub with the washed goods, a moderate fire is kindled. At the same time, the pump is set a-going, either by the hand of a workman or by machinery. Thus, the lixivium in its progressively heating state, is made to circulate continually down through the stuffs. But when it finally attains the boiling temperature, the piston rod and piston are removed, and the pressure of the included steam alone, forces the liquid up the vertical pipe, and along the horizontal one in an uninterrupted stream. The valve at the bottom of the tub, yielding to the accumulated weight of the liquid, opens from time to time, and replaces the lixivium in the boiler.

This most ingenious self-acting apparatus, was invented by Mr. John Laurie of Glasgow; and a representation of it accompanies Mr. Ramsay's excellent article, Bleaching, in the Edinburgh Encyclopædia. By its means, labour is spared, the negligence of servants is guarded against, and fully one-fourth of alkali saved.

It is of great consequence to heat the liquid very slowly at first. Hasty boiling is incompatible with good bleaching. When the ley seems to be impregnated with colouring matter, the fire is lowered, and the liquid drawn off by a stop-cock; at the same time that water, at first hot and then cold, is run in at top, to separate all the dark coloured lixivium. The goods are then taken out and well washed, either by the hand with the wash stocks, or by the rotatory wooden wheel with hollow compartments, called the dash wheel. The strength of the alkaline lixivium is varied by different bleachers. A solution of potash, rendered caustic by lime, of the specific gravity 1.014, or containing a little more than 1 per cent of pure potash, is used by many bleachers. The Irish bleachers use barilla-lixivium chiefly, and of inferior alkaline power. The routine of operations may be conveniently presented in a tabular form.

A parcel of goods consists of 360 pieces of those linens which are called Britannias. Each piece is 35 yards long, weighing on an average, 10 pounds. Hence, the weight of the whole is 3600 pounds avoirdupois. These linens are first washed, and then subjected to the acetous fermentation, as above described. They then undergo the following operations:—

1. Bucked with 60 lbs. pearl ashes, washed and exposed on the field.

2. do. with 80 lbs. do. do. do.
3. do. 90 potashes do. do.
4. do. 80 do. do. do.
5. do. 80 do. do. do.
6. do. 50 do. do. do.
7. do. 70 do. do. do.
8. do. 70 do. do. do.

9. Soured one night in dilute sulphuric acid.

10. Bucked with 50 lbs. pearl ashes, washed and exposed.

11. Immersed in the oxymuriate of potash for 12 hours.

12. Boiled with 30 lbs. pearl ashes, washed and exposed.

13. do. 30 do. do. do.
13. Soured and washed.

The linens are then taken to the rubbing board, and well rubbed with a strong lather of black soap, after which they are well washed in pure spring water. At this period they are carefully examined, and those which are fully bleached are laid aside to be blued and made up for the market. Those which are not fully white, are returned to be boiled and steeped in the oxymuriate of potash, and soured until they are fully white. By the above process, 690 lbs. of commercial alkali are used in bleaching 360 pieces of linen, each measuring 35 yards. Hence, the expenditure of alkali would be a little under 2 lbs. a-piece, were it not that some part of the above linens may not be thoroughly whitened. It will, therefore, be a fair average, to allow 2 lbs. for each piece of such goods.

On the above process we may remark, that many enlightened bleachers have found it advantageous to apply the souring at a more early period, as well as the oxymuriatic solution. According to Dr. Stephenson, in his elaborate paper on the linen and hempen manufactures, published by the Belfast Literary Society, 10 noggins, or quarter pints of oil of vitriol, are sufficient to make 200 gallons of souring. This gives the proportion, by measure, of 640 water to 1 of acid. Mr. Parkes, in describing the bleaching of calicoes in his Chemical Essays, says, that, throughout Lancashire, one *measure* of sulphuric acid is used with 46 of water, or one *pound* of the acid to 25 pounds of water; and he states, that a scientific calico printer in Scotland makes his sours to have the specific gravity 1.0254 at 110° of Fahrenheit; which dilute acid contains at least 1-25th of oil of vitriol. Five or six hours' immersion is employed.

In a note Mr. Parkes adds, that in bleaching common goods, and such as are not designed for the best printing, the specific gravity of the sours is varied from 1.0146 to 1.0238, if taken at the atmospheric temperature. Most bleachers use the strongest alkaline lixiviums at first, and the weaker afterwards. As to the strength of the oxymuriatic steeps, as the bleacher terms them, it is difficult to give certain data, from the variableness of the chlorides of potash and lime.

Mr. Parkes, in giving the process of the Scotch bleacher, says, that after the calicoes have been singed, steeped, and squeezed, they are boiled four successive times, for 10 or 12 hours each, in a solution of caustic potash of a specific gravity from 1.0127 to 1.0156, and washed thoroughly between each boiling. "They are then immersed in a solution of the oxymuriate of potash, originally of the strength of 1.0625, and afterwards reduced with 24 times its measure of water. In this preparation they are suffered to remain 12 hours." Dr. Stephenson says, that, for coarse linens, the steep is made by dissolving 1 lb. of oxymuriate of lime in 3 gallons of water, and afterwards diluting with 25 additional gallons. The ordinary specific gravity of the oxymuriate of lime steeps, by Mr. Ramsay, is 1.005. But from these *data*, little can be learned; because oxymuriate of lime is always more or less mixed with common muriate of lime, or chloride of calcium, a little of which has a great effect on the hydrometric indications. The period of immersion is 10 or 12 hours. Many bleachers employ gentle and long continued boiling without bucking. The operation of souring was long ago effected by butter milk, but it is more safely and advantageously performed by the dilute sulphuric acid uniformly combined with the water by much agitation.

Mr. Tennent's ingenious mode of uniting chlorine with pulverulent lime, was one of the greatest improvements in practical bleaching. When this chloride is well prepared and properly applied, it will not injure the most delicate muslin. Magnesia has been suggested as a substitute for lime, but the high price of this alkaline earth, must be a bar to its general employment. The muriate of lime solution resulting from the action of unbleached cloth on that of the oxymuriate, if too strong, or too long applied, would weaken the texture of cloth, as Sir H. Davy has shown. But the bleacher is on his guard against this accident; and the process of souring, which follows most commonly the oxymuriatic steep, thoroughly removes the adhering particles of lime.

Mr. Parkes informs us, that calicoes for madder work, or resist work, or for the fine pale blue dipping, cannot without injury be bleached with oxymuriate of lime. They require, he says, oxymuriate of potash. I believe this to be a mistake. Test liquors made by dissolving indigo in sulphuric acid, and then diluting the sulphate with water, or with infusion of cochineal, are employed to measure the blanching power of the oxymuriatic or chloridic solutions. But they are all more or less uncertain, from the changeableness of these colouring matters. I have met with indigo of apparently excellent quality, of which four parts were required to saturate the same weight of oxymuriate of lime, as was saturated by three parts of another indigo. Such coloured liquors, however, though they give no absolute measure of chlorine, afford useful means of comparison to the bleacher.

Some writers have recommended lime and sulphuret of lime as detergent substances instead of alkali; but I believe no practical bleacher of respectability would trust to them. Lime should always be employed, however, to make the alkalis caustic; in which state their detergent powers are greatly increased.

The coarser kinds of muslin are bleached by steeping, washing, and then boiling them in a weak solution of pot and pearl ashes. They are next washed, and afterwards boiled in soap alone, and then soured in very dilute sulphuric acid. After being washed from the sour, they are boiled with soap, washed, and immersed in the solution of chloride of lime or potash. The boiling in soap, and immersion in the oxymuriate, is repeated, until the muslin is of a pure white colour. It is finally soured and washed in pure spring water. The same series of operations is used in bleaching fine muslins, only soap is used in the boilings commonly to the exclusion of pearl ash. Fast *coloured* cottons are bleached in the following way:—After the starch or dressing is well removed by cold water, they are gently boiled with soap, washed, and immersed in a moderately strong solution of oxymuriate of potash. This process is repeated till the white parts of the cloth are sufficiently pure. They are then soured in dilute sulphuric acid. If these operations be well conducted, the colours, instead of being impaired, will be greatly improved, having acquired a delicacy of tint which no other process can impart.

After immersing cloth or yarn in alkaline ley, if it be exposed to the action of steam heated to 222°, in a strong vessel, it will be in a great measure bleached. This operation is admirably adapted to the cleansing of hospital linen.

The following is the practice followed by a very skilful bleacher of muslins near Glasgow.

"In fermenting muslin goods, we surround them with our spent leys from the temperature of 100° to 150° F. according to the weather, and allow them to ferment for 36 hours. In boiling 112 lbs. = 112 pieces of yard-wide muslin, we use 6 or 7 lbs. of ashes, and 2 lbs. of soft soap, in 360 gallons of water, and allow them to boil for 6 hours; then wash them, and boil them again, with 5 lbs. of ashes, and 2 lbs. of soft soap, in the same quantity of water, and allow them to boil 3 hours; then wash them with water, and immerse them into the solution of oxymuriate of lime, at 5 on the test tube, and allow them to remain from 6 to 12 hours; next wash them, and immerse them into diluted sulphuric acid at the specific gravity of 3½ on Twaddle's hydrometer = 1.0175, and allow them to remain an hour. They are now well washed, and boiled with 2½ lbs. of ashes, and 2 lbs. of soap, for half an hour; afterwards washed and immersed into the oxymuriate of lime as before, at the strength of 3 on the test tube, which is stronger than the former, and allowed to remain for 6 hours. They are again washed and immersed into diluted sulphuric acid at the specific gravity of 3 on Twaddle's hydrometer = 1.015. If the goods be strong, they will require another boil, steep, and sour. At any rate, the sulphuric acid is well washed out before they receive the finishing operation with starch.

"With regard to the lime, which some use instead of alkali, immediately after fermenting, the same weight of it is employed as of ashes. The goods are allowed to boil in it for 15 minutes, but not longer, otherwise the lime will injure the fabric."

The alkali may be recovered from the brown lixivia, by evaporating them to dryness and gentle ignition of the residuum. But, in most situations, the expense of fuel would exceed the value of the recovered alkali. A simpler mode is to boil the foul lixivium with quicklime, and a little pipe-clay and bullock's blood. After skimming, and subsidence, a tolerably pure ley is obtained.*

Under the head of chlorine, we have described the preparation of this article; and the chief circumstances respecting it to be noticed here is the apparatus, which must be on an extensive scale, and adapted to the purpose of immersing and agitating the goods to be bleached. The process of distillation may be performed in a large leaden alembic, *g g*, Plate I. fig. 1. supported by an iron trevet *f*, in an iron boiler *e*. This is heated by a furnace *b*, of which *a* is the ashhole, *c* the place for introducing the fuel; *d* is the handle of a stopper of burnt clay, for regulating the draught. To the top of the alembic is fitted a leaden cover *i*, which is luted on, and has three perforations: one for the curved glass or leaden funnel *h*, through which the sulphuric acid is to be poured in; one in the centre for the agitator *k*, made of iron coated with lead; and the third for the leaden tube *l*, three inches in diameter internally, through which the gas is conveyed into the tubulated leaden receiver *m*. To prevent the agitator from reaching to the bottom of the alembic, it is furnished with a conical leaden collar, adapted to a conical projection round the hole in the centre of the cover, to which it becomes so closely fitted by means of its rotatory motion, as to prevent the escape of the gas. The tube *l*, passing through the aperture *m*, to the bottom of the intermediate receiver nearly, which is two-thirds full of water, deposites there the little sulphuric acid that may arise; while the chlorine gas passes through the tube *n* into the wooden condenser *o o*. The agitator *p*, turned by its handle *t*, serves to accelerate the combination of the gas with the alkali, to which the horizontal pieces *q q*, projecting from the inside, likewise contribute. The cover of this receiver has a sloping groove *r*, to fit close on its edge, which is bevelled on each side; and a cock *s* serves to draw off the liquor. Mr. Tennent's chloride of lime has nearly superseded that plan.

The rags or other materials for making paper may be bleached in a similar manner: but it is best to reduce them first to the state of pulp, as then the acid acts more uniformly upon the whole substance.

For bleaching old paper: Boil your printed paper for an instant in a solution of caustic soda. That from kelp may be used. Steep it in soap-suds, and then wash it; after which it may be reduced to pulp. The soap may be omitted without much inconvenience. For old written paper to be worked up again: Steep it in water acidulated with sulphuric acid, and then wash it well before it is taken to the mill. If the water be heated it will be more effectual. To bleach printed paper, without destroying its texture: Steep the leaves in a caustic solution of soda, either hot or cold. and then in a solution of soap. Arrange them alternately between cloths, as paper-makers do thin sheets of paper when delivered from the form, and subject them to the press. If one operation do not render them sufficiently white. it may be repeated as often as necessary. To bleach old written paper, without destroying its texture: Steep the paper in water acidulated with sulphuric acid, either hot or cold, and then in a solution of oxygenated muriatic acid; after which immerse it in water, that none of the acid may remain behind. This paper, when pressed and dried, will be fit for use as before.

Blende. An ore of zinc.

Blood. The fluid which first presents itself to observation, when the parts of living animals are divided or destroyed, is the blood, which circulates with considerable velocity through vessels, called veins and arteries, distributed into every part of the system.

Recent blood is uniformly fluid, and of a saline taste. Under the microscope, it appears to be composed of a prodigious number of red globules, swimming in a transparent fluid. After standing for a short time, its parts separate into a thick red matter, or crassamentum, and a fluid called serum. If it be agitated till cold, it continues fluid; but a consistent polypous matter adheres to the stirrer, which by repeated ablutions with water becomes white, and has a fibrous appearance; the crassamentum becomes white and fibrous by the same treatment. If blood be received from the vein into warm water, a similar filamentous matter subsides, while the other parts are dissolved. Alkalis prevent the blood from coagulating; acids, on the contrary, accelerate that effect. In the latter case, the fluid is found to contain neutral salts, consisting of the acid itself, united with soda, which consequently must exist in the blood, probably in a disengaged state. Alcohol coagulates blood. On the water bath, blood affords an aqueous fluid, neither acid nor alkaline, but of a faint smell, and easily becoming putrid. A stronger heat gradually dries it, and at the same time reduces it to a mass of about one-eighth of its original weight.

* Blood usually consists of about 3 parts serum to one of cruor. The serum is of a pale greenish-yellow colour. Its specific gravity is about 1.029, while that of blood itself is 1.053. It changes sirup of violets to a green, from its containing free soda. At 156° serum coagulates, and resembles boiled white of egg. When this coagulated albumen is squeezed, a muddy fluid exudes, which has been called the serosity. According to Berzelius, 1000 parts of the serum of bullock's blood consist of 905. water, 79.99 albumen, 6.175 lactate of soda and extractive matter, 2.565 muriates of soda and potash, 1.52 soda and animal matter, and 4.75 loss. 1000 parts of serum of human blood consist, by the same chemist, of 905 water, 80 albumen, 6 muriates of potash and soda, 4 lactate of soda with animal matter, and 4.1 of soda, and phosphate of soda with animal matter. There is no gelatin in serum.

The cruor has a specific gravity of about 1.245. By making a stream of water flow upon it till the water runs off colourless, it is separated into insoluble fibrin, and the soluble colouring matter. A little albumen has also been found in cruor. The proportions of the former two, are 64 colouring matter, and 36 fibrin in 100. To obtain the colouring matter pure, we mix the cruor with 4 parts of oil of vitriol previously diluted with 8 parts of water, and expose the mixture to a heat of about 160 degrees for 5 or 6 hours. Filter the liquid while hot, and wash the residue with a few ounces of hot water. Evaporate the liquid to one-half, and add ammonia, till the acid be almost, but not entirely saturated. The colouring matter falls. Decant the supernatant liquid, filter and wash the residuum, from the whole of the sulphate of ammonia. When it is well drained, remove it with a platina blade, and dry it in a capsule.

When solid, it appears of a black colour, but becomes wine-red by diffusion through water, in which, however, it is not soluble. It has neither taste nor smell. Alcohol and ether convert it into an unpleasant smelling kind of adipocere. It is soluble both in alkalis and acids. It approaches to fibrin in its constitution, and contains iron in a peculiar state, $\frac{1}{3}$ of a per cent of the oxide of which may be extracted from it by calcination. The incinerated colouring matter weighs 1-80th of the whole; and these ashes consist of 50 oxide of iron, 7.5 subphosphate of iron, 6 phosphate of lime, with traces of magnesia, 20 pure lime, 16.5 carbonic acid and loss; or the two latter ingredients may be reckoned 32 carbonate of lime. Berzelius imagines that none of these bodies existed in the colouring matter, but only their bases, iron, phosphorus, calcium, carbon, &c. and that they were formed during the incineration. From the albumen of blood, the same proportion of ashes may be obtained, but no iron.

No good explanation has yet been given of the change of colour which blood undergoes from exposure to oxygen, and other gases. Under the exhausted receiver, carbonic acid gas is disengaged from it. The blood of the fœtus is darker coloured than that of the adult; it has no fibrin, and no phosphoric acid. The buffy coat of inflamed blood is fibrin; from which the colouring matter has precipitated by the greater liquidity or slowness of coagulation produced by the disease. The serum of such blood does not yield consistent albumen by heat. In diabetes mellitus, when the urine of the patient is loaded with sugar, the serum of the blood assumes the appearance of whey, according to Drs. Rollo and Dobson; but Dr. Wollaston has proved that it contains no sugar.*

Dr. Carbonel of Barcelona has employed serum of blood on an extensive scale in painting. Mixed with powdered quicklime or slaked lime, to a proper consistence, it is easily applied on wood, to which it thus gives a coating of a stone colour, that dries quickly, without any bad smell, and resists the action of sun and rain. The wood should be first covered with a coating of plaster; the composition must be mixed as it is used, and the serum must not be stale. It may be used too as a cement for water-pipes, and for stones for building under water.

* **Bloodstone.** See Calcedony.*

Blow-pipe. This simple instrument will be described under the article Laboratory.

* We shall here present our readers first with an abstract of Assessor Gahn's late valuable treatise on the *common* blow-pipe, and shall afterwards give an account of Dr. Clark's very interesting experiments with the *oxyhydrogen* blow-pipe.*

The substance to be submitted to the action of the blow-pipe must be placed on a piece of charcoal, or in a small spoon of platina, gold, or silver; or, according to Saussure, a plate of cyanite may sometimes be used. Charcoal from the pine is to be preferred, which should be well ignited and dried, that it may not crack. The sides, not the ends, of the fibres must be used, otherwise the substance to be fused spreads about, and a round bead will not be formed. A small hole is to be made in the charcoal, which is best done by a slip of plate iron bent longitudinally. Into this hole the substance to be examined must be put in very small quantity; if a very intense heat is to be used, it should not exceed the size of half a peppercorn.

The metallic spoons are used when the substance to be examined is intended to be exposed to the action of heat only, and might undergo some change by immediate contact with the charcoal. When the spoon is used, the flame of the blow-pipe should be directed to that part of it which contains the substance under examination, and not be immediately applied to the substance itself. The handle of the spoon may be inserted into a piece of charcoal: and if a very intense heat is required, the bowl of the spoon may be adapted to a hole in the charcoal. Small portions may be taken up by platina forceps. Salts and volatile substances are to be heated in a glass tube closed at one end, and enlarged according to circumstances, so as to form a small matrass.

When the alteration which the substance undergoes by the mere action of heat has been observed, it will be necessary to examine what further change takes place when

when it is melted with various fluxes, and how far it is capable of reduction to the metallic state.

These fluxes are,

1. Microcosmic salt; a compound of phosphoric acid, soda, and ammonia.
2. Subcarbonate of soda, which must be free from all impurity, and especially from sulphuric acid, as this will be decomposed, and sulphuret of soda will be formed, which will dissolve the metals we wish to reduce, and produce a bead of coloured glass with substances that would otherwise give a colourless one.
3. Borax, which should be first freed from its water of crystallization.

These are kept powdered in small phials; and when used, a sufficient quantity may be taken up by the moistened point of a knife: the moisture causes the particles to cohere, and prevents their being blown away when placed on the charcoal. The flux must then be melted to a clear bead, and the substance to be examined placed upon it. It is then to be submitted to the action, first of the exterior, and afterwards of the interior flame, and the following circumstances to be carefully observed:—

1. Whether the substance is dissolved; and, if so,
2. Whether with or without effervescence, which would be occasioned by the liberation of carbonic acid, sulphurous acid, oxygen, gaseous oxide of carbon, &c.
3. The transparency and colour of the glass while cooling.
4. The same circumstances after cooling.
5. The nature of the glass formed by the exterior flame, and
6. By the interior flame.
7. The various relations to each of the fluxes.

It must be observed that soda will not form a bead on charcoal, but with a certain degree of heat will be absorbed. When, therefore, a substance is to be fused with soda, this flux must be added in very small quantities, and a very moderate heat used at first, by which means a combination will take place, and the soda will not be absorbed. If too large a quantity of soda has been added at first, and it has consequently been absorbed, a more intense heat will cause it to return to the surface of the charcoal, and it will then enter into combination.

Some minerals combine readily with only very small portions of soda, but melt with difficulty if more be added, and are absolutely infusible with a larger quantity: and when the substance has no affinity for this flux, it is absorbed by the charcoal, and no combination ensues.

When the mineral or the soda contains sulphur or sulphuric acid, the glass acquires a deep yellow colour, which by the light of a lamp appears red, and as if produced by copper.

If the glass bead becomes opaque as it cools, so as to render the colour indistinct it should be broken, and a part of it mixed with more of the flux, until the colour becomes more pure and distinct. To render the colour more perceptible, the bead may be either compressed before it cools, or drawn out to a thread.

When it is intended to oxidate more highly a metallic oxide contained in a vitrified compound with any of the fluxes, the glass is first heated by a strong flame, and when melted is to be gradually withdrawn from the point of the blue flame. This operation may be repeated several times, permitting the glass sometimes to cool, and using a jet of large aperture with the blow-pipe.

The *reduction* of metals is effected in the following manner: The glass bead, formed after the manner already pointed out, is to be kept in a state of fusion on the charcoal as long as it remains on the surface, and is not absorbed, that the metallic particles may collect themselves into a globule. It is then to be fused with an additional quantity of soda, which will be absorbed by the charcoal, and the spot where the absorption has taken place is to be strongly ignited by a tube with a small aperture. By continuing this ignition, the portion of metal which was not previously reduced will now be brought to a metallic state; and the process may be assisted by placing the bead in a smoky flame, so as to cover it with soot that is not easily blown off.

The greatest part of the beads which contain metals are frequently covered with a metallic splendour, which is most easily produced by a gentle, fluttering, smoky flame, when the more intense heat has ceased. With a moderate heat the metallic surface remains; and by a little practice it may generally be known whether the substance under examination contains a metal or not. But it must be observed, that the glass of borax sometimes assumes externally a metallic splendour.

When the charcoal is cold, that part impregnated with the fused mass should be taken out with a knife, and ground with distilled water in a crystal, or what is much better, an agate mortar. The soda will be dissolved; the charcoal will float, and may be poured off; and the metallic particles will remain in the water, and may be examined. In this manner most of the metals may be reduced.

Relations of the Earths and Metallic Oxides before the Blow-pipe.

I. THE EARTHS.

Barytes, when containing water, melts and spreads on the charcoal. Combined with sulphuric acid, it is converted, in the *interior* flame, into a sulphuret, and is absorbed by the charcoal, with effervescence, which continues as long as it is exposed to the action of the instrument.

Strontites. If combined with carbonic acid, and held in small thin plates with platina forceps in the *interior* flame, the carbonic acid is driven off; and on the side of the plate farthest from the lamp, a red flame is seen sometimes edged with green, and scarcely perceptible but by the flame of a lamp. Sulphate of strontites is reduced in the *interior* flame to a sulphuret. Dissolve this in a drop of muriatic acid, add a drop of alcohol, and dip a small bit of stick in the solution; it will burn with a fine red flame.

Lime. The carbonate is easily rendered caustic by heat; it evolves heat on being moistened, and is afterwards infusible before the blow-pipe. The sulphate is easily reduced to sulphuret, and possesses, besides, the property of combining with fluor at a moderate heat, forming a clear glass, The fluor should be rather in excess.

Magnesia produces, like the strontites, an intense brightness in the flame of the blow-pipe. A drop of solution of cobalt being added to it, and it being then dried and strongly ignited, a faint reddish colour like flesh is produced, which, however, is scarcely visible by the light of a lamp. And magnesia may by this process be detected in compound bodies, if they do not contain much metallic matter, or a proportion of alumina exceeding the magnesia. Some inference as to the quantity of the magnesia may be drawn from the intensity of the colour produced.

All these alkaline earths, when pure, are readily fusible in combination with the fluxes into a clear, colourless glass, without effervescence; but on adding a further quantity of the earth, the glass becomes opaque.

Alumina combines more slowly with the fluxes than the preceding earths do, and forms a clear glass, which does not become opaque. But the most striking character of alumina is the bright blue colour it acquires from the addition of a drop of nitrate of cobalt, after having been dried and ignited for some time. And its presence may be detected in this manner in compound minerals, where the metallic substances are not in great proportion, or the quantity of magnesia large. Alumina may be thus detected in the agalmatolite.

II. THE METALLIC OXIDES.

Arsenic flies off accompanied by its characteristic smell, resembling garlic. When larger pieces of white arsenic are heated on a piece of ignited charcoal, no smell is perceived. To produce this effect the white oxide must be reduced, by being mixed with powdered charcoal. If arsenic is held in solution; it may be discovered by dipping into the solution a piece of pure and well-burned charcoal, which is afterwards to be dried and ignited.

Chrome. Its green oxide, the form in which it most commonly occurs, and to which it is reduced by heating in the common air, exhibits the following properties: it is fusible with *microcosmic salt*, in the *interior* flame, into a glass which at the instant of its removal from the flame, is of a violent hue, approaching more to the dark blue or red, according to the proportion of chrome. After cooling, the glass is bluish-green, but less blue than the copper glass. In the *exterior* flame the colour becomes brighter, and less blue, than the former. With *borax* it forms a bright yellowish, or yellow-red glass, in the *exterior* flame; and in the *interior* flame, this becomes darker and greener, or bluish-green. The reduction with soda has not been examined.

Molybdic acid melts by itself upon the charcoal with ebullition, and is absorbed. In a platina spoon it emits white fumes, and is reduced in the *interior* flame to molybdous acid, which is blue; but in the *exterior* flame it is again oxidated, and becomes white. With *microcosmic salt*, in the *exterior* flame, a small proportion of the acid gives a green glass, which by gradual additions of the acid passes through yellow-green to reddish, brownish, and hyacinth-brown, with a slight tinge of green. In the *interior* flame the colour passes from yellow-green, through yellow-brown and brown-red, to black; and if the proportion of acid be large, it acquires a metallic lustre, like the sulphuret, which sometimes remains after the glass has cooled. Molybdic acid is but little dissolved by *borax*. In the *exterior* flame the glass acquires a gray-yellow colour. In the *interior* flame, a quantity of black particles is precipitated from the clear glass, and leaves it almost colourless when the quantity of molybdenum is small, and blackish when the proportion is larger. If to a glass formed of this acid and microcosmic salt a little borax be added, and the mixture fused in the *exterior* flame, the colour becomes instantly reddish-brown; in the *interior* flame the black particles are also separated, but in smaller quantity. By long continued heat the colour of the glass is diminished, and it appears yellower by the light of a lamp than by day-light. This acid is not reduced by soda in the interior flame.

Tungstic acid becomes upon the charcoal at first brownish-yellow, is then reduced to a brown oxide, and lastly becomes black without melting or smoking. With *microcosmic salt* it forms in the *interior* flame a pure blue glass, without any violet tinge; in the *exterior* flame this colour disappears, and re-appears again in the *interior*. With *borax*, in the *internal* flame, and in small proportions it forms a colourless glass, which, by increasing the proportion of the acid, becomes dirty gray, and then reddish. By long exposure to the *external* flame it becomes transparent, but as it cools it becomes muddy, whitish, and changeable into red when seen by day-light. It is not reduced.

Oxide of Tantalum undergoes no change by itself, but is readily fused with *microcosmic salt* and with *borax*, into a clear colourless glass, from which the oxide may be precipitated by heating and cooling it alternately. The glass then becomes opaque, and the oxide is not reduced.

Oxide of Titanium becomes yellowish when ignited in a spoon, and upon charcoal dark brown. With *microcosmic salt* it gives in the *interior* flame a fine violet-coloured glass, with more of blue than that from manganese. In the *exterior* flame this colour disappears. With borax it gives a dirty hyacinth colour. Its combinations with soda have not been examined.

Oxide of Cerium becomes red-brown when ignited. When the proportion is small it forms with the fluxes a clear colourless glass, which by increasing the proportion of oxide becomes yellowish-green while hot. With *microcosmic salt*, if heated a long time in the *internal* flame, it gives a clear colourless glass. With *borax*, under similar circumstances, it gives a faint yellow-green glass while warm, but colourless when cold. Exposed again for some time to the *external* flame, it becomes reddish-yellow, which colour it partly retains when cold. If two transparent beads of the compound with microcosmic salt and with borax be fused together, the triple compound becomes opaque and white. Flies off by reduction.

Oxide of Uranium. The yellow oxide by ignition becomes green or greenish brown. With *microcosmic salt* in the *interior* flame it forms a clear yellow glass, the colour of which becomes more intense when cold. If long exposed to the *exterior* flame, and frequently cooled, it gives a pale yellowish red-brown glass, which becomes greenish as it cools. With *borax* in the *interior* flame a clear, colourless, or faintly green glass, is formed, containing black particles, which appear to be the metal in its lowest state of oxidation. In the *exterior* flame this black matter is dissolved if the quantity be not too great, and the glass becomes bright yellowish-green, and after further oxidation yellowish-brown. If brought again into the *interior* flame, the colour gradually changes to green, and the black matter is again precipitated, but no further reduction takes place.

Oxide of Manganese gives with *microcosmic salt* in the *exterior* flame a fine amethyst colour, which disappears in the *interior* flame. With *borax* it gives a yellowish hyacinth red glass.

When the manganese, from its combination with iron, or any other cause, does not produce a sufficiently intense colour in the glass, a little nitre may be added to it while in a state of fusion, and the glass then becomes dark violet while hot, and reddish violet when cool: is not reduced.

Oxide of Tellurium, when gently heated, becomes first yellow, then light red, and afterwards black. It melts and is absorbed by the charcoal, and is reduced with a slight detonation, a greenish flame, and a smell of horse-raddish. *Microcosmic salt* dissolves it without being coloured.

Oxide of Antimony is partly reduced in the *exterior* flame, and spreads a white smoke on the charcoal. In the *interior* flame it is readily reduced by itself, and with soda. With microcosmic salt and with borax it forms a hyacinth-coloured glass. Metallic antimony, when ignited on charcoal, and remaining untouched, becomes covered with radiating acicular crystals of white oxide. Sulphuret of antimony melts on charcoal, and is absorbed.

Oxide of Bismuth melts readily in a spoon to a brown glass, which becomes brighter as it cools. With *microcosmic salt* it forms a gray-yellow glass, which loses its transparency, and becomes pale, when cool. Add a further proportion of oxide, and it becomes opaque. With *borax* it forms a gray glass, which decrepitates in the *interior* flame, and the metal is reduced and volatilized. It is most readily reduced by itself on charcoal.

Oxide of Zinc becomes yellow when heated, but whitens as it cools. A small proportion forms with *microcosmic salt* and with *borax* a clear glass, which becomes opaque on increasing the quantity of oxide. A drop of nitrate of cobalt being added to the oxide, and dried and ignited, it becomes green. With *soda* in the *interior* flame it is reduced, and burns with its characteristic flame, depositing its oxide upon the charcoal. By this process zinc may be easily detected even in the automolite. Mixed with oxide of copper, and reduced, the zinc will be fixed, and brass be obtained. But one of the most unequivocal characters of the oxide of zinc is to dissolve it in vinegar, evaporate the solution to dryness, and expose it to the flame of a lamp, when it will burn with its peculiar flame.

Oxide of Iron produces with *microcosmic salt* or *borax* in the *exterior* flame, when cold, a yellowish glass, which is blood-red while hot. The protoxide forms with these fluxes a green glass, which, by increasing the proportion of the metal, passes through bottle-green to black and opaque. The glass from the oxide becomes green in the *interior* flame, and is reduced to protoxide, and becomes attractible by the magnet. When placed on the wick of a candle, it burns with the crackling noise peculiar to iron.

Oxide of Cobalt becomes black in the *exterior*, and gray in the *interior* flame. A small proportion forms with *microcosmic salt* and with *borax* a blue glass, that with borax being the deepest. By transmitted light the glass is reddish. By farther additions of the oxide it passes through dark blue to black. The metal may be precipitated from the dark blue glass by inserting a steel wire into the mass while in fusion. It is malleable if the oxide has been free from arsenic, and may be collected by the magnet; and is distinguished from iron by the absence of any crackling sound when placed on the wick of a candle.

Oxide of Nickel becomes black at the extremity of the *exterior* flame, and in the *interior* greenish-gray. It is dissolved readily, and in large quantity, by *microcosmic salt*. The glass, while hot, is a dirty dark red, which becomes paler and yellowish as it cools. After the glass has cooled, it requires a large addition of the oxide to produce a distinct change of colour. It is nearly the same in the *exterior* and *interior* flame, being slightly reddish in the latter. Nitre added to the bead makes it froth, and it becomes red-brown at first, and afterwards paler. It is easily fusible with *borax*, and the colour resembles the preceding. When this glass is long exposed to a high degree of heat in the *interior* flame, it passes from reddish to blackish and opaque; then blackish-gray, and translucent; then paler reddish-gray, and clearer; and, lastly, transparent; and the metal is precipitated in small white metallic globules. The red colour seems here to be produced by the entire fusion or solution of the oxide, the black by incipient reduction, and the gray by the minute metallic particles before they combine and form small globules. When a little soda is added to the glass formed with borax, the reduction is more easily effected, and the metal collects itself into one single globule. When this oxide contains iron, the glass retains its own colour while hot, but assumes that of the iron as it cools.

Oxide of Tin, in form of hydrate, and in its highest degree of purity, becomes yellow when heated, then red, and when approaching to ignition, black. If iron or lead be mixed with it, the colour is dark brown when heated. These colours become yellowish as the substance cools. Upon charcoal in the *interior* flame it becomes and continues white; and, if originally white and free from water, it undergoes no change of colour by heating. It is very easily reduced without addition, but the reduction is promoted by adding a drop of solution of soda or potash.

Oxide of Lead melts, and is very quickly reduced, either without any addition, or when fused with microcosmic salt or borax. The glass not reduced is black.

Oxide of Copper is not altered by the exterior flame, but becomes protoxide in the interior. With both *microcosmic salt* and *borax* it forms a yellow-green glass while hot, but which becomes blue-green as it cools. When strongly heated in the *interior* flame, it loses its colour, and the metal is reduced. If the quantity of oxide is so small that the green colour is not perceptible, its presence may be detected by the addition of a little tin, which occasions a reduction of the oxide to protoxide, and produces an opaque, red glass. If the oxide has been fused with borax, this colour is longer preserved; but if with microcosmic salt, it soon disappears by a continuance of heat.

The copper may also be precipitated upon iron, but the glass must be first saturated with iron. Alkalis or lime promote this precipitation. If the glass containing copper be exposed to a smoky flame, the copper is superficially reduced, and the glass covered while hot with an iridescent pellicle, which is not always permanent after cooling. It is very easily reduced by soda. Salts of copper, when heated before the blow-pipe, give a fine green flame.

Oxide of Mercury before the blow-pipe becomes black, and is entirely volatilized. In this manner its adulteration may be discovered.

The other metals may be reduced by themselves, and may be known by their own peculiar characters.

* Under the particular mineral species their habitudes with the blow-pipe are given.

Dr. Robert Hare, Professor of Natural Philosophy in the University of Philadelphia, published, in the first volume of Bruce's Mineralogical Journal, an account of very intense degrees of heat, which he had produced and directed on different bodies, by a jet of flame, consisting of hydrogen and oxygen gases, in the proportion requisite for forming water. The gases were discharged from separate gasometers, and were brought in contact only at a common orifice or nozzle of small diameter, in which their two tubes terminated.†

In the first number of the Journal of Science and Arts, is a description of a blowpipe contrived by Mr. Brooke, and executed by Mr. Newman, consisting of a strong iron box, with a blow-pipe nozzle and stop-cock, for regulating the emission of air, which had been previously condensed into the box, by means of a syringe screwed into its top. For this fine invention we are ultimately indebted to Sir H. Davy. John George Children, Esq. first proposed to him this application of Newman's apparatus for condensed air or oxygen, immediately after Sir H. had discovered that the explosion from oxygen and hydrogen would not communicate through very small apertures; and he first tried the experiment himself with a fine glass capillary tube. The flame was not visible at the end of this tube, being overpowered by the brilliant star of the glass ignited at the aperture.

Dr. Clarke, after being informed by Sir H. Davy that there would be no danger of explosion in burning the compressed gases, by suffering them to pass through a fine thermometer tube, $\frac{1}{80}$ of an inch diameter, and three inches in length; commenced a series of experiments, which were attended with most important and striking results. By the suggestion of Professor Cumming, there has been enclosed in the iron box, a small cylinder of safety, about half filled with oil, and stuffed at top with fine wire gauze. The condensed gases must pass from the large chamber into this small one, up through the oil, and then across the gauze, before they can reach the stopcock and blow-pipe nozzle. By this means, the dangerous explosions which had occurred so frequently, as would have deterred a less intrepid experimenter than Dr. Clarke, are now obviated. It is still, however, a prudent precaution, to place a wooden screen between the box and the operator. The box is about five inches long, four broad, and three deep. The syringe is joined to the top of the box by a stop-cock. Near the upper end of the syringe, a screw nozzle is fixed in it at right angles, to which the stop-cock of a bladder containing the mixed gases may be attached. When we wish to inject the gases, it is proper to draw the piston to the top, before opening the lower stop-cock, lest the flame of the jet should be sucked backward, and cause explosion. It is likewise necessary to see that no little explosion has dislodged the oil from the safety cylinder. A bubbling noise is heard when the oil is present. A slight excess of hydrogen is found to be advantageous.

Platinum is not only fused the instant it is brought in contact with the flame of the ignited gases, but the melted metal runs down in drops. Dr. Clarke has finely fused the astonishing quantity of half an ounce at once, by this jet of flame. In small quantities, it burns like iron wire. Palladium melted like lead. Pure lime becomes a wax-yellow vitrification. A lambent purple flame always accompanies its fusion. The fusion of magnesia is also attended with combustion. Strontites fused with a flame, of an intense amethystine colour, and after some minutes there appeared a small oblong mass of shining matter in its centre. Silex instantly melted into a deep orange-coloured glass, which was partly volatilized. Alumina melted with great rapidity into globules of a yellowish transparent glass. In these experiments, supports of charcoal, platinum or plumbago, were used with the same effect. The alkalis were fused and volatilized the instant they came in contact with the flame, with an evident appearance of combustion.

The following refractory native compounds were fused. Rock crystal, white quartz, noble opal, flint, calcedony, Egyptian jasper, zircon, spinelle, sapphire, topaz, cymophane, pycnite, andalusite, wavelite, rubellite, hyperstene, cyanite, talc, serpentine, hyalite, lazulite, gadolinite, leucite, apatite, Peruvian emerald, Siberian beryl, potstone, hydrate of magnesia, subsulphate of alumina, pagodite of China, Iceland spar, common chalk, Arragonite, diamond.

Gold exposed on pipe-clay to a flame, was surrounded with a *halo* of a lively rose colour, and soon volatilized. Stout iron wire was rapidly burned. Plumbago was fused into a magnetic bead. Red oxide of titanium fused, with partial combustion. Red ferriferous copper, blende, oxides of platinum, gray oxide of manganese, crystallized oxide of manganese, wolfram, sulphuret of molybdenum, siliceo-calcareous titanium, black oxide of cobalt, pechblende, siliciferous oxide of cerium, chromate of iron, and ore of iridium, were all, except the second and last, reduced to the metallic state, with peculiar, and for the most part, splendid phenomena. Jade, mica, amianthus, asbestus, melt like wax before this potent flame.

But the two most surprising of Dr. Clarke's experiments were, the fusion of the meteoric stone from l'Aigle, and its conversion into *iron;* and the reduction of *barium,* from the earth barytes and its salts. Some nitrate of barytes, put into a cavity, at the end of a stick of charcoal, was exposed to the ignited gas. It fused with vehement ebullition, and metallic globules were clearly discernible in the midst of the boiling fluid, suddenly forming, and as suddenly disappearing. On checking the flame, the cavity of the charcoal was studded over with innumerable globules of a metal of the most brilliant lustre and whiteness, resembling the purest platinum after fusion. Some globules were detached and dropped into naphtha, where they retained for some time their metallic aspect. Their specific gravity was 4.00.

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† My memoir on the supply and application of the blow-pipe, in which the fusion of the pure earths, and volatilization of platinum, were first mentioned as practicable, was published in a separate pamphlet twelve years before the article on the compound blow-pipe appeared in Bruce's Journal. This was a republication of a paper previously presented by Professor Silliman to the Connecticut Academy of Sciences.

Dr. Clarke fused together a bead of barium and one of platinum, each weighing one grain. The bronze coloured alloy weighed two grains, proving a real combination. The alloy of barium and iron is black and brittle. Barium is infusible before the blow-pipe, *per se;* but with borax it dissolves like barytes, with a chrysolite green colour, and disclosing metallic lustre to the file. The alloy of barium and copper is of a vermilion colour. When silex is mixed into a paste with lamp-oil, and exposed on a cavity of charcoal to the flame, it runs readily into beads of various colours. If these be heated in contact with iron, an alloy of silicium and iron is obtained, which discloses a metallic surface to the file. Magnesium and iron may be alloyed in the same way.

By using from two to three volumes of hydrogen to one of oxygen, and directing the flame on pure barytes, supported on pincers of slate, Dr. Clarke has more lately revived barium in larger quantities, so as to exhibit its qualities for some time. It gradually, however, passes again into pure barytes. Muriate of rhodium, placed in a charcoal crucible, yielded the metal rhodium, brilliant like platinum. It is malleable on the anvil. Oxide of uranium, from Cornwall, was also reduced to the metallic state.†

We shall conclude this article by the following experiment of Dr. Clarke's: If you take up two pieces of lead foil and platinum foil of equal dimensions, and roll them together, and place the roll upon charcoal, and direct the flame of a candle cautiously towards the edges of the roll, at about a red heat, the two metals will combine with a sort of explosive force, scattering their melted particles off the charcoal, and emitting light and heat in a very surprising manner. Then there will remain upon the charcoal a film of glass; which by further urging the flame towards it, will melt into a highly transparent globule of a sapphire blue colour. Also, if the platinum and lead be placed beside each other, as soon as the platinum becomes heated, you will observe a beautiful play of blue light upon the surface of the lead, becoming highly iridescent before it melts.*

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† How far Dr. Ure has done me justice in this article, will be seen more fully in the strictures which I have lately published on "Clarke's gas blow-pipe," in Silliman's Journal, No. 2, vol. 2. But it may be sufficient to subjoin the following article translated into No. 1, vol. 3d. of the same journal, from the Annales de Chimie. From this it appears, that Dr. Clarke's plagiarisms are not likely to receive the countenance in France, which he has managed to procure for them in his own country.

"The blow-pipe of Hare was described in the Annals of Chemistry, (Vol. 45, p. 113.) It is supplied by two streams, one of hydrogen and the other of oxygen, which do not mix till the moment of their combustion; and consequently are attended by no kind of danger. This blow-pipe is in this respect far preferable to that of Newman, or rather of Brooke, who appears to have been the first inventor, and it is not inferior to it, or only in a very slight degree, in intensity of heat. We can besides supply it with hydrogen gas and oxygen gas, compressed each in its own reservoir; but, if we were to judge of it by the effects produced by this instrument, and by that of Brooke, there is but little advantage in having recourse to this means.

"Lavoisier, as is well known, by directing oxygen gas upon burning charcoal, succeeded in melting and volatilizing some substances, which, till that time, had been considered as infusible and fixed. (Mém. de l'Acad. 1782 et 1783). He melted alumine, and many of its mixtures; but he did not succeed in melting silex, barytes, lime and magnesia.

"Mr. Hare, by means of his blow-pipe, perfectly melted alumine, silex and barytes, but with great difficulty, lime and magnesia. He brought silver and gold to a state of ebullition, and succeeded, almost instantly, in volatilizing completely, globules of platina of more than a line in diameter. (Ann. de Chim. XLV. 134. et LX. 82.)

"Some years afterwards, Mr. Silliman, Professor of Chemistry and Mineralogy, who had co-operated in the early experiments of Mr. Hare, performed new ones, which were published in 1813, in the first volume of the Memoirs of the Connecticut Academy of Arts and Sciences; we proceed to give the principal results.

"Alumine was perfectly melted into a milk white enamel.

"Silex, into a colourless glass.

"Barytes and strontian into a grayish white enamel.

"Glucine and Zircon were perfectly melted into a white enamel.

"Lime, prepared by the calcination of Carrara marble, was melted into a perfectly white and brilliant enamel.

"The splendor of the light was such that the eye, when naked, and even when protected by deeply coloured glasses, could not sustain it. The lime was seen to become rounded at the angles, and gradually to sink down; and in a few seconds, there remained only a small globular mass.

"Magnesia was affected almost exactly as lime; the light reflected was equally vivid; the surface was melted into small vitreous globules.

* **Blue (Prussian).** A combination of oxide of iron with an acid distinguished by the name of the *ferro-prussic.* See Acid (Prussic), and Iron.*

Blue (Saxon). The best Saxon blue colour may be given by the following composition:

Mix one ounce of the best powdered indigo with four ounces of sulphuric acid, in a glass bottle or matrass, and digest it for one hour with the heat of boiling water, shaking the mixture at different times: then add twelve ounces of water to it, and stir the whole well, and when grown cold, filter it.

Mr. Poerner adds one ounce of good dry potash at the end of twenty-four hours, and lets this stand as much longer, before he dilutes it with water. The cloth should be prepared with alum and tartar.

Bog Ores. See Ores of Iron.

* **Bole.** A massive mineral, having a perfectly conchoidal fracture, a glimmering internal lustre, and a shining streak. Its colours are yellow-red, and brownish-black, when it is called mountain soap. It is translucent, or opaque. Soft, so as to be easily cut, and to yield to the nail. It adheres to the tongue, has a greasy feel, and falls to pieces in water. Sp. gr. 1.4 to 2. It may be polished. If it be immersed in water after it is dried, it falls asunder with a crackling noise. It occurs in wacke and basalt, in Silesia, Hessia, and Sienna in Italy, and also in the clifts of the Giant's Causeway, Ireland. The black variety is found in the trap rocks of the Isle of Sky.*

Bolognian Stone. Lemery reports, that an Italian shoemaker, named Vincenzo Casciarolo, first discovered the phosphoric property of the Bolognian stone. It is the ponderous spar, or native sulphate of barytes.

If it be first heated to ignition, then finely powdered, and made into a paste with mucilage; and this paste, divided into pieces a quarter of an inch thick, and dried in a moderate heat, be exposed to the heat of a wind furnace, by placing them loose in the midst of the charcoal; a pyrophorus will be obtained, which, after a few minutes' exposure to the sun's rays, will give light enough in the dark to render the figures on the dial-plate of a watch visible.

* **Boletic Acid.** See Acid (Boletic).*

* **Boletus.** A genus of mushroom, of which several species have been subjected to chemical examination by M. M. Braconnot and Bouillon La Grange.

1. *Boletus juglandis*, in 1260 parts, yielded, 1118.3 water, 95.68 fungin, 18 animal matter insoluble in alcohol, 12 osmazome, 7.2 vegetable albumen, 6 fungate of potash, 1.2 adipocere, 1.12 oily matter, 0.5 sugar of mushrooms, and a trace of phosphate of potash.

2. *Boletus laricis*, used on the continent in medicine, under the name of *agaric.* It is in white, light friable pieces, of which the outside is like dark-coloured leather. Its taste at first sweetish, soon passes into bitterness and acrimony. Its infusion in water is yellowish, sweet-tasted, and reddens vegetable blues. It contains muriate of potash, sulphate of lime, and sulphate of potash. Water boiled on agaric, becomes gelatinous on cooling; and if the water be dissipated by evaporation, ammonia is exhaled by the addition of lime. Resin of a yellow colour, with a bitter sour taste, may be extracted from it by alcohol. It yields benzoic acid, by Sheele's process. The strong acids act with energy on agaric, and the nitric evolves oxalic acid. Fixed alkalis convert it into a red jelly, which emits an ammoniacal smell.

"Platina was not only melted, but volatilized with strong ebullition.

"A great number of minerals, such as rock crystal, chalcedony, beryl, Peruvian emerald, peridot (chrysolite), amphigene (leucite), disthène (sappare), corundum, zircon, spinel-ruby, &c. melted with the greatest facility.

"In subsequent experiments, which Mr. Silliman has communicated to us, platina, gold, silver, and many other metals were not only rapidly vaporized, but entered, at the same time, into beautiful and vivid combustion.

"Although the experiments of Mr. Silliman date in 1812, we have thought that they ought to be known upon our continent. They demonstrate, on the one hand, that Mr. Clarke has been anticipated in America, with respect to the fusion of bodies in the flame of hydrogen and oxygen; —and on the other, that the blow-pipe of Hare gives results almost perfectly identical with those of Brooke."

3. *Boletus igniarius* is found in most countries, and particularly in the Highlands of Scotland, on the trunks of old ash and other trees. The French and Germans prepare it abundantly for making *tinder*, by boiling in water, drying, beating it, and steeping it in a solution of nitre, and again drying it. In France it is called *amadou*, in this country *German tinder*. It has been recommended in surgery, for stopping hæmorrhage from wounds. It imparts to water a deep brown colour, and an astringent taste. The liquid consists of sulphate of lime, muriate of potash, and a brown extractive matter. When the latter is evaporated to dryness, and burned, it leaves a good deal of potash. Phosphates of lime and magnesia, with some iron, are found in the insoluble matter. Alkalis convert it with some difficulty into a soapy liquid, exhaling ammonia. No benzoic acid, and little animal matter, are found in this boletus.

4. *Boletus pseudo-igniarius*, yielded to Braconnot, water, fungin, a sweetish mucilage, boletate of potash, a yellow fatty matter, vegetable albumen, a little phosphate of potash, acetate of potash, and fungic acid combined with a base.

5. *Boletus viscidus* was found by Braconnot to be composed, in a great measure, of an animal mucus, which becomes cohesive by heat.*

Bone. The bones of men and quadrupeds owe their great firmness and solidity to a considerable portion of the phosphate of lime which they contain. When these are rasped small, and boiled in water, they afford gelatinous matter, and a portion of fat or oil, which occupied their interstices.

* Calcined human bones, according to Berzelius, are composed, in 100 parts, of 81.9 phosphate of lime, 3 fluate of lime, 10 lime, 1.1 phosphate of magnesia, 2 soda, and 2 carbonic acid. 100 parts of bones by calcination are reduced to 63. Fourcroy and Vauquelin found the following to be the composition of 100 parts of ox bones: 51 solid gelatin, 37.7 phosphate of lime, 10 carbonate of lime, and 1.3 phosphate of magnesia; but Berzelius gives the following as their constituents; 33.3 cartilage, 55.35 phosphate of lime, 3 fluate of lime, 3.85 carbonate of lime, 2.05 phosphate of magnesia, and 2.45 soda, with a little common salt.

About 1-30th of phosphate of magnesia was obtained from the calcined bones of fowls, by Fourcroy and Vauquelin. When the enamel of teeth, rasped down, is dissolved in muriatic acid, it leaves no albumen, like the other bones. Fourcroy and Vauquelin state its components to be, 27.1 gelatin and water, 72.9 phosphate of lime. Messrs. Hatchett and Pepys rate its composition at 78 phosphate of lime, 6 carbonate of lime, and 16 water and loss. Berzelius, on the other hand, found only 2 per cent of combustible matter in teeth. The teeth of adults, by Mr. Pepys, consist of 64 phosphate of lime, 6 carbonate of lime, 20 cartilage, and 10 water or loss. The fossil bones from Gibraltar, are composed of phosphate of lime and carbonate, like burnt bones. Much difference of opinion exists with regard to the existence of fluoric acid in the teeth of animals, some of the most eminent chemists taking opposite sides of the question. It appears that bones buried for many centuries, still retain their albumen, with very little diminution of its quantity.*

Fourcroy and Vauquelin discovered phosphate of magnesia in all the bones they examined, except human bones. The bones of the horse and sheep afford about 1-36th of phosphate of magnesia; those of fish nearly the same quantity as those of the ox. They account for this by observing, that phosphate of magnesia is found in the urine of man, but not in that of animals, though both equally take in a portion of magnesia with their food.

The experiments of Mr. Hatchett show, that the membranous or cartilaginous substance, which retains the earthy salts within its interstices, and appears to determine the shape of the bone, is albumen. Mr. Hatchett observes, that the enamel of tooth is analogous to the porcellanous shells, while mother of pearl approaches in its nature to true bone.

A curious phenomenon with respect to bones is the circumstance of their acquiring a red tinge, when madder is given to animals with their food. The bones of young pigeons will thus be tinged of a rose colour in twenty-four hours, and of a deep scarlet in three days; but the bones of adult animals will be a fortnight in acquiring a rose colour. The bones most remote from the heart are the longest in acquiring this tinge. Mr. Gibson informs us, that extract of logwood too, in considerable quantity, will tinge the bones of young pigeons purple. On desisting from the use of this food, however, the colouring matter is again taken up into the circulation, and carried off, the bones regaining their natural hue in a short time. It was said by Du Hamel, that the bones would become coloured and colourless in concentric layers, if an animal were fed alternately one week with madder, and one week without; and hence he inferred, that the bones were formed in the same manner as the woody parts of trees. But he was mistaken in the fact; and indeed had it been true, with the inference he naturally draws from it, the bones of animals must have been out of all proportion larger than they are at present.

Bones are of extensive use in the arts. In their natural state, or dyed of various colours, they are made into handles of knives and forks, and numerous articles of turnery. We have already noticed the manufacture of volatile alkali from bones, the coal of which forms bone black; or if they be afterwards calcined to whiteness in the open air, they constitute the bone ashes, of which cupels are made, and which, finely levigated, are used for cleaning articles of paste, and some other trinkets, by the name of burnt hartshorn. The shavings of hartshorn, which is a species of bone, afford an elegant jelly; and the shavings of other bones, of which those of the calf are the best, are often employed in their stead.

On this principle, Mr. Proust has recommended an economical use of bones, particularly with a view to improve the subsistence of the soldier. He first chops them into small pieces, throws them into a kettle of boiling water, and lets them boil about a quarter of an hour. When this has stood till it is cold, a quantity of fat, excellent for culinary purposes when fresh, and at any time fit for making candles, may be taken off the liquor. This in some instances amounted to an eighth, and in others even to a fourth, of the weight of the bones. After this the bones may be ground, and boiled in eight or ten times their weight of water, of which that already used may form a part, till about half is wasted, when a very nutritious jelly will be obtained. The boiler should not be of copper, as this metal is easily dissolved by the jelly; and the cover should fit very tight, so that the heat may be greater than that of boiling water, but not equal to that of Papin's digester, which would give it an empyreuma. The bones of meat that have been boiled, are nearly as productive as fresh bones; but Dr. Young found those of meat that had been roasted afforded no jelly, at least by simmering, or gentle boiling.

* BORACIC ACID. See ACID (BORACIC). This acid has been found native on the edges of hot springs, near Sapo in the territory of Florence; also attached to specimens from the Lipari Islands, and from Monte Rotondo, to the west of Sienna. It is in small pearly scales, and also massive; fusing at the flame of a candle into a glassy globule. It consists, by Klaproth's analysis, of 86 boracic acid, 11 ferruginous sulphate of manganese, and 3 sulphate of lime.*

* BORACITE. Borate of magnesia. It is found in cubic crystals, whose fracture is uneven, or imperfectly conchoidal. Shining greasy lustre; translucent; so hard as to strike fire with steel; of a yellowish, grayish, or greenish-white. Sp. grav. 2.56. It becomes electric by heat; and the diagonally opposite solid angles, are in opposite electrical states. It fuses into a yellow enamel, after emitting a greenish light.

Vauquelin's analysis gives, 83.4 boracic acid, and 16.6 magnesia. It occurs in gypsum in the Kalkberg in the duchy of Brunswick, and at Segeberg, near Kïel in Holstein.*

BORAX. The origin of Borax was for a long time unknown in Europe. Mr. Grill Abrahamson, however, sent some to Sweden in the year 1772, in a crystalline form, as dug out of the earth in Thibet, where it is called Pounnxa, Mypoun, and Houipoun: it is said to have been also found in Saxony, in some coal pits.

It does not appear that borax was known to the ancients, their chrysocolla being a very different substance, composed of the rust of copper, triturated with urine. The word borax is found for the first time in the works of Geber.

Borax is not only found in the East, but likewise in South America. Mr. Anthony Carera, a physician established at Potosi, informs us, that this salt is abundantly obtained at the mines of Riquintipa, and those in the neighbourhood of Escapa, where it is used by the natives in the fusion of copper ores.

The purification of borax by the Venetians and the Hollanders, was for a long time kept secret. Chaptal finds, after trying all the processes in the large way, that the simplest method consists in boiling the borax strongly, and for a long time, with water. This solution being filtered, affords by evaporation crystals, which are somewhat foul, but may be purified by repeating the operation.

Purified borax is white, transparent, rather greasy in its fracture, affecting the form of six-sided prisms, terminating in three-sided or six-sided pyramids. Its taste is styptic; it converts sirup of violets to a green: and when exposed to heat, it swells up, boils, loses its water of crystallization, and becomes converted into a porous, white, opaque mass, commonly called Calcined Borax. A stronger heat brings it into a state of quiet fusion; but the glassy substance thus afforded, which is transparent, and of a greenish-yellow colour, is soluble in water, and effloresces in the air. It requires about eighteen times its weight of water to dissolve it at the temperature of sixty degrees of Fahrenheit; but water at the boiling heat dissolves three times this quantity. Its component parts, according to Kirwan, are, boracic acid 34, soda 17, water 47. For an account of the neutral borate of soda, and other compounds of this acid, see ACID (BORACIC).

Borax is used as an excellent flux in docimastic operations. It enters into the composition of reducing fluxes, and is of the greatest use in analysis by the blow-pipe. It may be applied with advantage in glass manufactories; for when the fusion turns out bad, a small quantity of borax re-establishes it. It is more especially used in soldering; it assists the fusion of the solder, causes it to flow, and keeps the surface of the metals in a soft or clean state, which facilitates the operation. It is scarcely of any use in medicine. Its acid, called *Sedative Salt*, is used by some physicians; and its name sufficiently indicates its supposed effects. Mixed with shell lac, in the proportion of one part to five, it renders the lac soluble by digestion in water heated near boiling.

* **Boron.** The combustible basis of boracic acid, which see.*

* **Botany Bay Resin** exudes spontaneously from the trunk of the *acarois resinifera* of New Holland, and also from the wounded bark. It soon solidifies by the sun, into pieces of a yellow colour of various sizes. It pulverizes easily without caking; nor does it adhere to the teeth when chewed. It has a slightly sweet astringent taste. It melts at a moderate heat. When kindled, it emits a white fragrant smoke. It is insoluble in water, but imparts to it the flavour of storax. Out of nine parts, six are soluble in water, and astringent to the taste; and two parts are woody fibre.*

* **Botryolite** is a mineral which occurs in mamillary concretions, formed of concentric layers; and also in botryoidal masses, white and earthy. Its colour is pearl and yellowish-gray, with sometimes reddish-white concentric stripes. It has a rough and dull surface, and a pearly lustre internally. Fracture delicate stellular fibrous. Translucent on the edges. Brittle, but moderately hard. Sp. grav. 2.85. It is composed of 36 silica, 39.5 boracic acid, 13.5 lime, 1 oxide of iron, 6.5 water. It froths and fuses before the blow-pipe into a white glass. It is found in a bed of gneiss, near Arendahl in Norway. It is regarded by some as a variety of Datholite.*

***Bournonite.** An antimonial sulphuret of lead.*

Bovey Coal. This is of a brown or brownish-black colour; and lamellar texture; the laminæ are frequently flexible when first dug, though generally they harden when exposed to the air. It consists of wood penetrated with petroleum or bitumen, and frequently contains pyrites, alum, and vitriol; its ashes afford a small quantity of fixed alkali, according to the German chemists; but according to Mr. Mills, they contain none. By distillation it yields an ill-smelling liquor, mixed with volatile alkali and oil, part of which is soluble in alcohol, and part insoluble, being of a mineral nature.

It is found in England, France, Italy, Switzerland, Germany, Iceland, &c.

* **Boyle's Fuming Liquor.** Hydroguretted sulphuret of ammonia.*

Brain of Animals. The brain has long been known to anatomists; but it is only of late years that chemists have paid it any attention. It is a soft white substance, of a pulpy saponaceous feel, and little or no smell. Exposed to a gentle heat, it loses moisture, shrinks to about a fourth of its original bulk, and becomes a tenacious mass of a greenish-brown colour. When completely dried, it becomes solid, and friable like old cheese. Exposed to a strong heat, it gives out ammonia, swells up, melts into a black pitchy mass, takes fire, burns with much flame and a thick pungent smoke, and leaves a coal difficult of incineration.

In its natural state, or moderately dried, it readily forms an emulsion by trituration with water, and is not separated by filtration. This solution lathers like soap-suds, but does not turn vegetable blue colours green. Heat throws down the dissolved brain in a flocculent form, and leaves an alkaline phosphate in solution. Acids separate a white coagulum from it; and form salts with bases of lime, soda, and ammonia. Alcohol too coagulates it.

Caustic fixed alkalis act very powerfully on brain even cold, evolving much ammonia and caloric. With heat they unite with it into a saponaceous substance.

The action of alcohol on brain is most remarkable. When Fourcroy treated it four times in succession with twice its weight of well rectified alcohol, boiling it a quarter of an hour each time, in a long-necked matrass with a grooved stopple, the three first portions of alcohol, decanted boiling deposited by cooling brilliant laminæ of a yellowish-white colour, diminishing in quantity each time. The fourth deposited very little. The cerebral matter had lost 5-8ths of its weight; and by the spontaneous deposition, and the subsequent evaporation of the alcohol, half of this was recovered in needly crystals, large scales, or granulated matter. The other half was lost by volatilization. This crystallized substance, of a fatty appearance, was agglutinated into a paste under the finger; but did not melt at the heat of boiling water, being merely softened. At a higher temperature it suddenly acquired a blackish-yellow colour, and exhaled during fusion an empyreumatic and ammoniacal smell. This shows that it is not analogous to spermaceti, or to adipocere; but it seems more to resemble the fat lamellated crystals contained in some biliary calculi, which, however, do not soften at a heat of 234° F. or become ammoniacal and empyreumatic at this temperature, as the crystalline cerebral oil does.

A portion of this concrete oil, separated from the alcohol by evaporation in the sun, formed a granulated pellicle on its surface, of a consistence resembling that of soft soap. It was of a yellower colour than the former, and had a marked smell of animal extract, and a perceptible saline taste. It was diffusible in water, gave it a milky appearance, reddened litmus paper, and did not become really oily, or fusible after the manner of an oil, till it had given out ammonia, and deposited carbon, by the action of fire or caustic alkalis.

A similar action of alcohol on the brain, nerves, and spinal marrow, is observed after long maceration in it cold, when they are kept as anatomical preparations.

* Vauquelin analyzed the brain and found the following constituents in 100 parts: 80 water, 4.53 white fatty matter, 0.7 reddish fatty matter, 7. albumen, 1.12 osmazome, 1.5 phosphorus, 5.15 acids, salts, and sulphur. The medulla oblongata and nerves have the same chemical composition.*

The spontaneous change that brain undergoes in certain situations, has already been noticed under the article Adipocere.

Brandy. This well known fluid is the spirit distilled from wine. The greatest quantities are made in Languedoc, where this manufacture, upon the whole so pernicious to society, first commenced. It is obtained by distillation in the usual method, by a still, which contains five or six quintals of wine, and has a capital and worm tube applied. Its peculiar flavour depends, no doubt, on the nature of the volatile principles, or essential oil, which come over along with it, and likewise, in some measure, upon the management of the fire, the wood of the cask in which it is kept, &c. It is said, that our rectifiers imitate the flavour of brandy, by adding a small proportion of nitrous ether to the spirit of malt or molasses. See Alcohol.

Brass. An elegant yellow-coloured compound metal, consisting of copper combined with about one-third of its weight of zinc. The best brass is made by cementation of calamine, or the ore of zinc, with granulated copper. See Copper.

Brassica Rubra. The red cabbage affords a very excellent test both for acids and alkalis; in which it is superior to litmus, being naturally blue, turning green with alkalis, and red with acids. * The minced leaves may be dried before the fire till they become quite crisp, when they ought to be put into a bottle, and corked up. Hot water poured on a little of the dried leaves, affords an extemporaneous test liquor for acids and alkalis. The purple petals of violets may be preserved in the same way; as well as those of the pink coloured *lychnis*, and scarlet rose.*

Brazil Wood. The tree that affords this wood, the cæsalpina crista, is of the growth of the Brazils in South America, and also of the Isle of France, Japan, and elsewhere. It is chiefly used in the process of dyeing. The wood is considerably hard, is capable of a good polish, and is so heavy that it sinks in water. Its colour is pale when newly cut, but it becomes deeper by exposure to the air. The various specimens differ in the intensity of their colour; but the heaviest is reckoned the most valuable. It has a sweetish taste when chewed, and is distinguished from red sanders, or sandal, by its property of giving out its colour with water, which this last does not.

If the brazil wood be boiled in water for a sufficient time, it communicates a fine red colour to that fluid. The residue is very dark coloured, and gives out a considerable portion of colouring matter to a solution of alkali. Alcohol extracts the colour from brazil wood, as does likewise the volatile alkali; and both these are deeper than the aqueous solution. The spirituous tincture, according to Dufay, stains warm marble of a purplish red, which on increasing the heat becomes violet; and if the stained marble be covered with wax, and considerably heated, it changes through all the shades of brown, and at last becomes fixed of a chocolate colour.

* The colours imparted to cloth by brazil wood are of little permanence. A very minute portion of alkali, or even soap darkens it into purple. Hence paper stained with it may be used as a test of saturation with the salts. Alum added to the decoction of this wood, occasions a fine crimson-red precipitate, or lake, which is increased in quantity by the addition of alkali to the liquor. The crimson-red colour is also precipitated by muriate of tin; but it is darkened by the salts of iron. Acids change it to yellow, from which, however, solution of tin restores it to its natural hue. The extract of brazil wood reddens litmus paper, by depriving it of the alkali which darkens it.*

Bread. I am not acquainted with any set of experiments regularly instituted and carried into effect, for ascertaining what happens in the preparation of bread. Farinaceous vegetables are converted into meal by trituration, or grinding in a mill, and when the husk or bran has been separated by sifting or bolting, the powder is called flour. This is composed of a small quantity of mucilaginous saccharine matter, soluble in cold water, much starch, which is scarcely soluble in cold water, but combines with that fluid by heat, and an adhesive gray substance insoluble in water, alcohol, oil, or ether, and resembling an animal substance in many of its properties. See WHEAT, STARCH, GLUTEN (VEGETABLE), MUCILAGE.

When flour is kneaded together with water, it forms a tough paste, containing these principles very little altered, and not easily digested by the stomach. The action of heat produces a considerable change in the gluten, and probably in the starch, rendering the compound more easy to masticate, as well as to digest. Hence the first approaches towards the making of bread consisted in parching the corn, either for immediate use as food, or previous to its trituration into meal; or else in baking the flour into unleavened bread, or boiling it into masses more or less consistent; of all which we have sufficient indications in the histories of the earlier nations, as well as in the various practices of the moderns. It appears likewise from the Scriptures, that the practice of making leavened bread is of very considerable antiquity; but the addition of yeast, or the vinous ferment, now so generally used, seems to be of modern date.

Unleavened bread in the form of small cakes, or biscuit, is made for the use of shipping in large quantities; but most of the bread used on shore is made to undergo, previous to baking, a kind of fermentation, which appears to be of the same nature as the fermentation of saccharine substances; but is checked and modified by so many circumstances, as to render it not a little difficult to speak with certainty and precision respecting it. See FERMENTATION.

When dough or paste is left to undergo a spontaneous decomposition in an open vessel, the various parts of the mass are differently affected, according to the humidity, the thickness or thinness of the part, the vicinity or remoteness of fire, and other circumstances less easily investigated. The saccharine part is disposed to become converted into alcohol, the mucilage has a tendency to become sour and mouldy, while the gluten in all probability verges toward the putrid state. An entire change in the chemical attractions of the several component parts must then take place in a progressive manner, not altogether the same in the internal and more humid parts as in the external parts, which not only become dry by simple evaporation, but are acted upon by the surrounding air. The outside may therefore become mouldy or putrid, while the inner part may be only advanced to an acid state. Occasional admixture of the mass would of course not only produce some change in the rapidity of this alteration, but likewise render it more uniform throughout the whole. The effect of this commencing fermentation is found to be, that the mass is rendered more digestible and light; by which last expression it is understood, that it is rendered much more porous by the disengagement of elastic fluid, that separates its parts from each other, and greatly increases its bulk. The operation of baking puts a stop to this process, by evaporating great part of the moisture which is requisite to favour the chemical attraction, and probably also by still farther changing the nature of the component parts. It is then bread.

Bread made according to the preceding method will not possess the uniformity which is requisite, because some parts may be mouldy, while others are not yet sufficiently changed from the state of dough. The same means are used in this case as have been found effectual in promoting the uniform fermentation of large masses. This consists in the use of a leaven or ferment, which is a small portion of some matter of the same kind, but in a more advanced stage of the fermentation. After the leaven has been well incorporated by kneading into fresh dough, it not only brings on the fermentation with greater speed, but causes it to take place in the whole of the mass at the same time; and as soon as the dough has by this means acquired a due increase of bulk from the carbonic acid, which endeavours to escape, it is judged to be sufficiently fermented, and ready for the oven.

The fermentation by means of leaven or sour dough is thought to be of the acetous kind, because it is generally so managed that the bread has a sour flavour and taste. But it has not been ascertained that this acidity proceeds from true vinegar. Bread raised by leaven is usually made of a mixture of wheat and rye, not very accurately cleared of the bran. It is distinguished by the name of rye bread; and the mixture of these two kinds of grain is called bread-corn, or meslin, in many parts of the kingdom, where it is raised on one and the same piece of ground, and passes through all the processes of reaping, threshing, grinding, &c. in this mixed state.

Yeast or barm is used as the ferment for the finer kinds of bread. This is the mucilaginous froth which rises to the surface of beer in its first stage of fermentation. When it is mixed with dough, it produces a much more speedy and effectual fermentation than that obtained by leaven, and the bread is accordingly much lighter, and scarcely ever sour. The fermentation by yeast seems to be almost certainly of the vinous or spirituous kind.

Bread is much more uniformly miscible with water than dough; and on this circumstance its good qualities most probably do in a great measure depend.

A very great number of processes are used by cooks, confectioners, and others, to make cakes, puddings, and other kinds of bread, in which different qualities are required. Some cakes are rendered brittle, or as it is called *short*, by an admixture of sugar or of starch. Another kind of brittleness is given by the addition of butter or fat. White of egg, gum-water, isinglass, and other adhesive substances, are used, when it is intended that the effect of fermentation shall expand the dough into an exceedingly porous mass. Dr. Percival has recommended the addition of salep, or the nutritious powder of the orchis root. He says, that an ounce of salep, dissolved in a quart of water, and mixed with two pounds of flour, two ounces of yeast, and eighty grains of salt, produced a remarkably good loaf, weighing three pounds two ounces; while a loaf made of an equal quantity of the other ingredients, without the salep, weighed but two pounds twelve ounces. If the salep be in too large quantity, however, its peculiar taste will be distinguishable in the bread. The farina of potatoes likewise, mixed with wheaten flour, makes very good bread. The reflecting chemist will receive considerable information on this subject from an attentive inspection of the receipts to be met with in treatises of cooking and confectionary.

* Mr. Accum, in his late Treatise on Culinary Poisons, states, that the inferior kind of flour which the London bakers generally use for making loaves, requires the addition of alum to give them the white appearance of bread made from fine flour. "The baker's flour is very often made of the worst kinds of damaged foreign wheat, and other cereal grains mixed with them in grinding the wheat into flour. In this capital, no fewer than six distinct kinds of wheaten flour are brought into the market. They are called fine flour, seconds, middlings, fine middlings, coarse middlings, and twenty-penny flour. Common garden beans and peas are also frequently ground up among the London bread flour.

"The smallest quantity of alum that can be employed with effect to produce a white, light, and porous bread from an inferior kind of flour, I have my own baker's authority to state, is from three to four ounces to a sack of flour weighing 240 pounds."

"The following account of making a sack or five bushels of flour into bread, is taken from Dr. P. Markham's considerations on the ingredients used in the adulteration of flour and bread, p. 21.

Five bushels of flour,
Eight ounces of alum,
Four lbs. salt,
Half a gallon of yeast mixed with about
Three gallons of water.

"Another substance employed by fraudulent bakers is subcarbonate of ammonia. With this salt they realize the important consideration of producing light and porous bread from spoiled, or what is technically called *sour flour*. This salt, which becomes wholly converted into a gaseous substance during the operation of baking, causes the dough to swell up into air bubbles, which carry before them the stiff dough, and thus it renders the dough porous; the salt itself is at the same time totally volatilized during the operation of baking."—"Potatoes are likewise largely, and perhaps constantly used by fraudulent bakers, as a cheap ingredient to enhance their profit."——"There are instances of convictions on record, of bakers having used gypsum, chalk, and pipe-clay, in the manufacture of bread."

Mr. E. Davy, Prof. of Chemistry at the Cork Institution, has made experiments, showing that from twenty to forty grains of common carbonate of magnesia, well mixed with a pound of the worst *new seconds* flour, materially improved the quality of the bread baked with it.

The habitual and daily introduction of a portion of alum into the human stomach, however small, must be prejudicial to the exercise of its functions, and particularly in persons of a bilious and costive habit. And besides, as the best sweet flour never stands in need of alum, the presence of this salt indicates an inferior and highly acescent food; which cannot fail to aggravate dyspepsia, and which may generate a calculous diathesis in the urinary organs. Every precaution of science and law ought therefore to be employed to detect and stop such deleterious adulterations. Bread may be analyzed for alum by crumbling it down when somewhat stale in distilled water, squeezing the pasty mass through a piece of cloth; and then passing the liquid through a paper filter. A limpid infusion will thus be obtained. It is difficult to procure it clear if we use new bread or hot water. A dilute solution of muriate of barytes dropped into the filtered infusion, will indicate by a white cloud, more or less heavy, the presence and quantity of alum. I find that genuine bread gives no precipitate by this treatment. The earthy adulterations are easily discovered by incinerating the bread at a red heat in a shallow earth vessel, and heating the residuary ashes with a little nitrate of ammonia. The earths themselves will then remain, characterized by their whiteness and insolubility.

The latest chemical treatise on the art of making bread, except the account given by Mr. Accum in his work on the *adulterations of food*, is the article Baking in the Supplement to the Encyclopædia Britannica,—a work adorned by the dissertations of Biot, Brande, Jeffrey, Lesley, Playfair, and Stewart.

Under *Process of Baking* we have the following statement: "An ounce of alum is then dissolved over the fire in a tin pot, and the solution poured into a large tub, called by the bakers the *seasoning-tub*. Four pounds and a half of salt are likewise put into the tub, and a pailful of hot water." Note on this passage.—"In London, where the goodness of bread is estimated entirely by its whiteness, it is usual with those bakers who employ flour of an inferior quality to add *as much* alum as common salt to the dough. Or in other words, the quantity of salt added is diminished one-half, and the deficiency supplied by an equal weight of alum. This improves the look of the bread very much, rendering it much whiter and firmer."

In a passage which we shall presently quote, our author represents the bakers of London joined in a conspiracy to supply the citizens with bad bread. We may hence infer, that the full allowance he assigns of 2¼ pounds of alum for every 2¼ pounds of salt, will be adopted in converting a sack of flour into loaves. But as a sack of flour weighs 280 pounds, and furnishes on an average 80 quartern loaves, we have 2¼ pounds divided by 80, or $\frac{15750 \text{ grains}}{80} =$ 197 grains, for the quantity present by this writer in a London quartern loaf. Yet in the very same page (39th of volume 2d) we have the following passage: "Alum is not added by all bakers. The writer of this article has been assured by several bakers of respectability, both in Edinburgh and Glasgow, on whose testimony he relies, and who made excellent bread, that they never employed any alum. The reason for adding it given by the London bakers is, that it renders the bread whiter, and enables them to separate readily the loaves from each other. This addition has been alleged by medical men, and is considered by the community at large as injurious to the health, by occasioning constipation. But if we consider the small quantity of this salt added by the baker, not quite 5½ grains to a quartern loaf, we will not readily admit these allegations. Suppose an individual to eat the seventh part of a quartern loaf a-day, he would only swallow eight-tenths of a grain of alum, or in reality not quite so much as half a grain, for one-half of this salt consists of water. It seems absurd to suppose that half a grain of alum, swallowed at different times during the course of a day, should occasion constipation." Is it not more absurd to state 2¼ pounds, or 36 ounces, as the alum adulteration of a sack of flour by the London bakers, and within a few periods to reduce the adulteration to *one* ounce?

That this voluntary abstraction of $\frac{35}{36}$ of the alum, and substitution of superior and more expensive flour, is not expected by him from the London bakers, is sufficiently evident from the following story: It would appear that some of his friends had invented a new yeast for fermenting dough by mixing a quart of beer barm with a paste made of ten pounds of flour and two gallons of boiling water, and keeping this mixture warm for six or eight hours.

"Yeast made in this way," says he, "answers the purposes of the baker much better than brewer's yeast, because it is clearer, and free from the hop mixture, which sometimes injures the yeast of the brewer. Some years ago the bakers of London, sensible of the superiority of this artificial yeast, invited a company of manufacturers from Glasgow to establish a manufactory of it in London, and promised to use no other. About 5000*l.* accordingly were laid out on buildings and materials, and the manufactory was begun on a considerable scale. The ale brewers, finding their yeast, for which they had drawn a good price, lie heavy on their hands, invited *all* the journeymen bakers to their cellars, gave them their full of ale, and promised to regale them in that manner every day, provided they would force their masters to take all their yeast from the ale brewers. The journeymen accordingly declared in a *body*, that they would work no more for their masters unless they gave up taking any more yeast from the new manufactory. The masters were obliged to comply; the new manufactory was stopped; and the *inhabitants of London were obliged to continue to eat worse bread, because it was the interest* of the ale brewers to sell the yeast. Such is the influence of journeymen bakers in the metropolis of England!"

This doleful diatribe seems [illegible] extravagant; for surely beer-yeast [illegible]erive nothing noxious to a porter-drinking people, from a slight impregnation of hops; while it must form probably a more energetic ferment than the fermented paste of the new company, which at any rate could be prepared in six or eight hours by any baker who found it to answer his purpose of making a pleasant eating bread. But it is a very serious thing for a lady or gentleman of sedentary habits, or infirm constitution, to have their digestive process daily vitiated by damaged flour, whitened with 197 grains of alum per quartern loaf. Acidity of stomach, indigestion, flatulence, headaches, palpitation, costiveness, and urinary calculus, may be the probable consequences of the habitual introduction of so much acidulous and acescent matter.

I have made many experiments on bread, and have found the proportion of alum very variable. Its quantity seems to be proportional to the badness of the flour; and hence when the best flour is used, no alum need be introduced. That alum is not necessary for giving bread its utmost beauty, sponginess, and agreeableness of taste, is undoubted, since the bread baked at the establishment of Mr. Harley of Willowbank, Glasgow, in which about 20 tons of flour are converted into loaves in the course of a week, unites every quality of appearance, with an absolute freedom from that acido-astringent drug. He uses six pounds of salt for every sack of flour; which from its good quality generally affords 83 or 84 quartern loaves of the legal weight, of four pounds five ounces and a half each. The loaves lose nine ounces in the oven. For an account of the constituents of wheat flour, see WHEAT.*

BRECCIA. An Italian term, frequently used by our mineralogical writers to denote such compound stones as are composed of agglutinated fragments of considerable size. When the agglutinated parts are rounded, the stone is called puddingstone. Breccias are denominated according to the nature of their component parts. Thus we have calcareous breccia, or marbles, and siliceous breccias, which are still more minutely classed, according to their varieties.

BREWING. See BEER, ALCOHOL, and FERMENTATION.

BRICK. Among the numerous branches of the general art of fashioning argillaceous earths into useful forms, and afterward hardening them by fire, the art of making bricks and tiles is by no means one of the least useful.

Common clay is scarcely ever found in a state approaching to purity on the surface of the earth. It usually contains a large proportion of siliceous earth. Bergmann examined several clays in the neighbourhood of Upsal, and made bricks, which he baked with various degrees of heat, suffered them to cool, immersed them in water for a considerable time, and then exposed them to the open air for three years. They were formed of clay and sand. The hardest were those into the composition of which a fourth part of sand had entered. Those which had been exposed for the shortest time to the fire were almost totally destroyed, and crumbled down by the action of the air; such as had been more thoroughly burned suffered less damage; and in those which had been formed of clay alone, and were half vitrified by the heat, no change whatever was produced.

On the whole he observes, that the proportion of sand to be used to any clay, in making bricks, must be greater the more such clay is found to contract in burning; but that the best clays are those which need no sand. Bricks should be well burned; but no vitrification is necessary, when they can be rendered hard enough by the mere action of the heat. Where a vitreous crust might be deemed necessary, he recommends the projection of a due quantity of salt into the furnace, which would produce the effect in the same manner as is seen in the fabrication of the English pottery called stone-ware.

A kind of bricks called fire-bricks are made from slate-clay, which are very hard, heavy, and contain a large proportion of sand. These are chiefly used in the construction of furnaces for steam-engines, or other large works, and in lining the ovens of glass-houses, as they will stand any degree of heat. Indeed they should always be employed where fires of any intensity are required.

* BRICKS (FLOATING). Bricks, that swim on water, were manufactured by the ancients; and Fabbroni discovered some years since a substance, at Castel del Piano, near Santa Fiora, between Tuscany and the States of the Church, from which similar bricks might be made. It constitutes a brown earthy bed, mixed with the remains of plants. Haüy calls it *talc pulverulent silicifère*, and Brochant considers it as a variety of *meerschaum*. The Germans name it *bergmehl*, (mountain meal), and the Italians *latte di luna*, (moon milk). By Klaproth's analysis, it consists of 79 silica, 5 alumina, 3 oxide of iron, 12 water, and 1 loss, in 100 parts. It agrees nearly in composition with *Kieselguhr*.*

BRIMSTONE. See SULPHUR.

* BRIONIA ALBA. A root used in medicine. By the analysis of Vauquelin, it is found to consist in a great measure of starch, with a bitter principle, soluble in water and alcohol, some gum, a vegeto-animal matter, precipitable by infusion of galls, some woody fibre, a little sugar, and supermalate and phosphate of lime. It has cathartic powers; but is now seldom prescribed by physicians.*

BROCATELLO. A calcareous stone or marble, composed of fragments of four colours, white, gray, yellow, and red.

BRONZE. A mixed metal, consisting chiefly of copper, with a small proportion of tin, and sometimes other metals. It is used for casting statues, cannon, bells, and other articles, in all which the proportions of the ingredients vary.

* BRONZITE. This massive mineral has a pseudo-metallic lustre, frequently resembling bronze. Its colour is intermediate between yellowish-brown and pinchbeck-brown. Lustre shining; structure lamellar

with joints, parallel to the lateral planes of a rhomboidal prism; the fragments are streaked on the surface. It is opaque in mass, but transparent in thin plates. White streak; somewhat hard, but easily broken. Sp. grav. 3.2. It is composed of 60 silica, 27.5 magnesia, 10.5 oxide of iron, and 0.5 water. It is found in large masses in beds of serpentine, near Kranbat, in Upper Stiria; and in a syenitic rock in Glen Tilt, in Perthshire.*

* **Brown Spar.** Pearl Spar, or Siderocalcite. It occurs massive, and in obtuse rhomboids with curvilinear faces. Its colours are white, red, and brown, or even pearl-gray and black. It is found crystallized in flat and acute double three-sided pyramids, in oblique six-sided pyramids, in lenses and rhombs. It is harder than calcareous spar, but yields to the knife. Its external lustre is shining, and internal pearly. Sp. gr. 2.88. Translucent, crystals semi-transparent; it is easily broken into rhomboidal fragments. It effervesces slowly with acids. It is composed of 49.19 carbonate of lime, 44.39 carbonate of magnesia, 3.4 oxide of iron, and 1.5 manganese, by Hisinger's analysis. Klaproth found 32 carbonate of magnesia, 7.5 carbonate of iron, 2 carbonate of manganese, and 51.5 carbonate of lime. There is a variety of this mineral of a fibrous texture, flesh-red colour, and massive.*

* **Brucia, or Brucine.** A new vegetable alkali, lately extracted from the bark of the false angustura, or *Brucea antidysenterica*, by M.M. Pelletier and Caventou. After being treated with sulphuric ether, to get rid of a fatty matter, it was subjected to the action of alcohol. The dry residuum from the evaporated alcoholic solution, was treated with Goulard's extract, or solution of sub-acetate of lead, to throw down the colouring matter, and the excess of lead was separated by a current of sulphuretted hydrogen. The nearly colourless alkaline liquid was saturated with oxalic acid, and evaporated to dryness. The saline mass being freed from its remaining colouring particles, by absolute alcohol, was then decomposed by lime or magnesia, when the *brucia* was disengaged. It was dissolved in boiling alcohol, and obtained in crystals, by the slow evaporation of the liquid. These crystals, when obtained by very slow evaporation, are oblique prisms, the bases of which are parallelograms. When deposited from a saturated solution in boiling water, by cooling, it is in bulky plates, somewhat similar to boracic acid in appearance. It is soluble in 500 times its weight of boiling water, and in 850 of cold. Its solubility is much increased by the colouring matter of the bark.

Its taste is exceedingly bitter, acrid, and durable in the mouth. When administered in doses of a few grains, it is poisonous, acting on animals like strychnia, but much less violently. It is not affected by the air. The dry crystals fuse at a temperature a little above that of boiling water, and assume the appearance of wax. At a strong heat, it is resolved into carbon, hydrogen, and oxygen; without any trace of azote. It combines with the acids, and forms both neutral and super-salts. Sulphate of brucia crystallizes in long slender needles, which appear to be four-sided prisms, terminated by pyramids of extreme fineness. It is very soluble in water, and moderately in alcohol. Its taste is very bitter. It is decomposed by potash, soda, ammonia, barytes, strontites, lime, magnesia, morphia, and strychnia. The bisulphate crystallizes more readily than the neutral sulphate. The latter is said to be composed of

Sulphuric acid,	8.84	5
Brucia,	91.16	51.582

Muriate of brucia forms in four-sided prisms, terminated at each end by an oblique face. It is permanent in the air, and very soluble in water. It is decomposed by sulphuric acid. Concentrated nitric acid destroys the alkaline basis of both these salts. The muriate consists of

Acid,	5.953	4.575
Brucia,	94.046	72.5

Phosphate of brucia, is a crystallizable, soluble, and slightly efflorescent salt. The nitrate forms a gummy-looking mass; the binitrate crystallizes in acicular four-sided prisms. An excess of nitric acid decomposes the brucia, into a matter of a fine red colour. Acetate and oxalate of brucia both crystallize. Brucia is insoluble in sulphuric ether, the fixed oils, and very slightly in the volatile oils. When administered internally, it produces tetanus, and acts upon the nerves without affecting the brain, or the intellectual faculties. Its intensity is to that of strychnia, as 1 to 12. From the discrepancies in the prime number for brucia, deduced from the above analyses, we see that its true equivalent remains to be determined. See *Journal de Pharmacie, Dec.* 1819.*

Brunswick Green. This is an ammoniaco-muriate of copper, much used for paper-hangings, and on the continent in oil painting. See Copper.

* **Buntkupferz.** Purple copper ore.*

Butter. The oily inflammable part of milk, which is prepared in many countries as an article of food. The common mode of preserving it is by the addition of salt, which will keep it good a considerable time, if in sufficient quantity. Mr. Eaton informs us, in his Survey of the Turkish Empire, that most of the butter used at Constantinople is brought from the Crimea and Kirban, and that it is kept sweet, by melting it while fresh over a very slow fire, and removing the scum as it rises. He adds that by melting butter in the Tartarian manner, and then salting it in ours, he kept it good and fine-tasted for two years; and that this melting if carefully done, injures neither the taste nor colour. Thenard, too, recommends the Tartarian method. He directs the melting to be done on a water-bath, or at a heat not exceeding 180° F.; and to be continued till all the caseous matter has subsided to the bottom, and the butter is transparent. It is then to be decanted, or strained through a cloth, and cooled in a mixture of pounded ice and salt, or at least in cold spring water, otherwise it will become lumpy by crystallizing, and likewise not resist the action of the air so well. Kept in a close vessel, and in a cool place, it will thus remain six months or more, nearly as good as at first, particularly after the top is taken off. If beaten up with one-sixth of its weight of the cheesy matter when used, it will in some degree resemble fresh butter in appearance. The taste of rancid butter, he adds, may be much corrected by melting and cooling in this manner.

Dr. Anderson has recommended another mode of curing butter, which is as follows: Take one part of sugar, one of nitre, and two of the best Spanish great salt, and rub them together into a fine powder. This composition is to be mixed thoroughly with the butter, as soon as it is completely freed from the milk in the proportion of one ounce to sixteen; and the butter thus prepared is to be pressed tight into the vessel prepared for it, so as to leave no vacuities. This butter does not taste well, till it has stood at least a fortnight; it then has a rich marrowy flavour, that no other butter ever acquires; and with proper care may be kept for years in this climate, or carried to the East Indies, if packed so as not to melt.

In the interior parts of Africa, Mr. Park informs us, there is a tree much resembling the American oak, producing a nut in appearance somewhat like an olive. The kernel of this nut, by boiling in water, affords a kind of butter, which is whiter, firmer, and of a richer flavour, than any he ever tasted made from cows' milk, and will keep without salt the whole year. The natives call it *shea toulou*, or tree butter. Large quantities of it are made every season.

BUTTER OF ANTIMONY. See ANTIMONY.

BUTTER OF CACAO. An oily concrete white matter, of a firmer consistence than suet, obtained from the cacao nut, of which chocolate is made. The method of separating it consists in bruising the cacao and boiling it in water. The greater part of the superabundant and uncombined oil contained in the nut is by this means liquefied, and rises to the surface, where it swims and is left to congeal, that it may be the more easily taken off. It is generally mixed with small pieces of the nut, from which it may be purified, by keeping it in fusion without water in a pretty deep vessel, until the several matters have arranged themselves according to their specific gravities. By this treatment it becomes very pure and white.

Butter of cacao is without smell, and has a very mild taste, when fresh; and in all its general properties and habitudes, it resembles fat oils; among which it must therefore be classed. It is used as an ingredient in pomatums.

BUTTER OF TIN. See TIN.

* BYSSOLITE. A massive mineral, in short and somewhate stiff filaments, of an olive-green colour, implanted perpendicularly like moss, on the surface of certain stones. It has been found at the foot of Mount Blanc, and also near Oisans-on-gneiss.*

C

CABBAGE (RED). See BRASSICA RUBRA.

CACAO (BUTTER OF). SEE BUTTER.

* CACHOLONG. A variety of quartz. It is opaque, dull on the surface, internally of a pearly lustre, brittle, with a flat conchoidal fracture, and harder than opal. Its colour is milk-white, yellowish, or grayish-white. It is not fusible before the blowpipe. Its sp. grav. is about 2.2. It is found in detached masses on the river Cach in Bucharia, in the trap-rocks of Iceland, in Greenland and the Ferroe Islands. According to Brongniart, cacholongs are found also at Champigny near Paris, in the cavities of a calcareous breccia, some of which are hard and have a shining fracture, while others are tender, light, adhere to the tongue, and resemble chalk.*

* CADMIUM. A new metal, first discovered by M. Stromeyer, in the autumn of 1817, in some carbonate of zinc which he

was examining in Hanover. It has been since found in the Derbyshire silicates of zinc.

The following is Dr. Wollaston's process for procuring Cadmium. It is distinguished by the usual elegance and precision of the analytical methods of this philosopher. From the solution of the salt of zinc supposed to contain cadmium, precipitate all the other metallic impurities by iron; filter and immerse a cylinder of zinc into the clear solution. If cadmium be present, it will be thrown down in the metallic state, and when redissolved in muriatic acid, will exhibit its peculiar character on the application of the proper tests.

Mr. Stromeyer's process consists in dissolving the substance which contains cadmium in sulphuric acid, and passing through the acidulous solution a current of sulphuretted hydrogen gas. He washes this precipitate, dissolves it in concentrated muriatic acid, and expels the excess of acid by evaporation. The residue is then dissolved in water, and precipitated by carbonate of ammonia, of which an excess is added, to redissolve the zinc and the copper that may have been precipitated by the sulphuretted hydrogen gas. The carbonate of cadmium being well washed, is heated to drive off the carbonic acid, and the remaining oxide is reduced by mixing it with lampblack, and exposing it to a moderate red heat in a glass or earthen retort.

The colour of cadmium is a fine white, with a slight shade of bluish gray, approaching much to that of tin, which metal it resembles in lustre and susceptibility of polish. Its texture is compact, and its fracture hackly. It crystallizes easily in octohedrons, and presents on its surface, when cooling, the appearance of leaves of fern. It is flexible, and yields readily to the knife. It is harder and more tenacious than tin; and, like it, stains paper, or the fingers. It is ductile and malleable, but when long hammered, it scales off in different places. Its sp. grav. before hammering, is 8 6040; and when hammered, it is 8.6944. It melts, and is volatilized under a red heat. Its vapour, which has no smell, may be condensed in drops like mercury, which, on congealing, present distinct traces of crystallization.

Cadmium is as little altered by exposure to the air as tin. When heated in the open air, it burns like that metal, passing into a smoke, which falls and forms a very fixed oxide, of a brownish-yellow colour. Nitric acid readily dissolves it cold; dilute sulphuric, muriatic, and even acetic acids, act feebly on it with the disengagement of hydrogen. The solutions are colourless, and are not precipitated by water.

Cadmium forms a single oxide, in which 100 parts of the metal are combined with 14.352 of oxygen. The prime equivalent of cadmium deduced from this compound seems to be very nearly 7, and that of the oxide 8. This oxide varies in its appearance according to circumstances, from a brownish-yellow to a dark brown, and even a blackish colour. With charcoal it is reduced with rapidity below a red heat. It gives a transparent colourless glass bead with borax. It is insoluble in water, but in some circumstances forms a white hydrate, which speedily attracts carbonic acid from the air, and gives out its water when exposed to heat.

The fixed alkalis do not dissolve the oxide of cadmium in a sensible degree; but liquid ammonia readily dissolves it. On evaporating the solution, the oxide falls in a dense gelatinous hydrate. With the acides it forms salts, which are almost all colourless, have a sharp metallic taste, are generally soluble in water, and possess the following characters:

1. The fixed alkalis precipitate the oxide in the state of a white hydrate. When added in excess, they do not redissolve the precipitate, as is the case with the oxide of zinc.

2. Ammonia likewise precipitates the oxide white, and doubtless in the state of hydrate; but an excess of the alkali immediately redissolves the precipitate.

3. The alkaline carbonates produce a white precipitate, which is an anhydrous carbonate. Zinc in the same circumstances gives a hydrous carbonate. The precipitate formed by the carbonate of ammonia is not soluble in an excess of this solution. Zinc exhibits quite different properties.

4. Phosphate of soda exhibits a white pulverulent precipitate. The precipitate formed by the same salt in solutions of zinc, is in fine crystalline plates.

5. Sulphuretted hydrogen gas, and the hydrosulphurets, precipitate cadmium yellow or orange. This precipitate resembles orpiment a little in colour, with which it might be confounded without sufficient attention. But it may be distinguished by being more pulverulent, and precipitating more rapidly. It differs particularly in its easy solubility muriatic acid, and in its fixity.

6. Ferroprussiate of potash precipitates solutions of cadmium white.

7. Nutgalls do not occasion any change.

8. Zinc precipitates cadmium in the metallic state in the form of dendritical leaves, which attach themselves to the zinc.

The carbonate consists, by Stromeyer, of

Acid,	100.00	25.4	2.750
Oxide,	292.88	74.6	8.054

The sulphate crystallizes in large rectangular transparent prisms, similar to sulphate of zinc, and very soluble in water. It effloresces in the air. At a strong red heat it gives out a portion of its acid, and becomes a subsulphate, which crystallizes in plates that dissolve with difficulty in water. The neutral sulphate consists of,

Acid,	100.00	38.3	5.000
Oxide,	161.12	61.7	8.056

100 parts of the salt takes 34.26 of water of crystallization. Nitrate of cadmium crystallizes in prisms or needles, usually grouped in rays. It is deliquescent Its constituents are,

Acid,	100.00	46	6.75000
Oxide,	117.58	54.	7.93665

100 parts of the dry salt take 28 31 water of crystallization. The muriate of cadmium crystallizes in small rectangular prisms, perfectly transparent, which effloresce easily when heated, and which are very soluble. It melts under a red heat, loses its water of crystallization, and on cooling assumes the form of a foliated mass, which is transparent, and has a lustre slightly metallic and pearly. In the air, it speedily loses its transparency, and falls down in a white powder. 100 parts of fused chloride are composed of,

Cadmium,	61.39	7.076
Chlorine,	38.61	4.450

Phosphate of cadmium is pulverulent, insoluble in water, and melts, when heated to redness, into a transparent vitreous body. It is composed of,

Acid,	100	3.54
Oxide,	225.49	8.00

Borate of cadmium is scarcely soluble in water. It consists of,

Acid,	27.88	3.079
Oxide,	72.12	8.000

Acetate of cadmium crystallizes in small prisms, usually disposed in stars, which are not altered by exposure to air, and are very soluble in water. The tartrate crystallizes in small scarcely soluble needles. The oxalate is insoluble. The citrate forms a crystalline powder, very little soluble.

100 parts of cadmium unite with 28.172 of sulphur, to form a sulphuret of a yellow colour, with a shade of orange. It is very fixed in the fire. It melts at a white-red heat, and on cooling, crystallizes in micaceous plates of the finest lemon-yellow colour. The sulphuret dissolves even cold in concentrated muriatic acid, with the disengagement of sulphuretted hydrogen gas; but the dilute acid has little effect on it, even with the assistance of heat. It is best formed by heating together a mixture of sulphur with the oxide, or by precipitating a salt of cadmium with sulphuretted hydrogen. It promises to be useful in painting.

Phosphuret of cadmium, made by fusing the ingredients together, has a gray colour, and a lustre feebly metallic. Muriatic acid decomposes it, evolving phosphuretted hydrogen gas. Iodine unites with cadmium, both in the moist and dry way. We obtain an iodide in large and beautiful hexahedral tables. These crystals are colourless, transparent, and not altered by exposure to air. Their lustre is pearly, approaching to metallic. It melts with extreme facility, and assumes, on cooling, the original form. At a high temperature, it is resolved into cadmium and iodine. Water and alcohol dissolve it with facility. It is composed of,

Cadmium,	100.00	8.000
Iodine,	227.43	18.1984?

Cadmium unites easily with most of the metals, when heated along with them out of contact of air. Most of its alloys are brittle and colourless. That of copper and cadmium is white, with a slight tinge of yellow. Its texture is composed of very fine plates. $\frac{1}{100}$ of cadmium communicates a good deal of brittleness to copper. At a strong heat the cadmium flies off. Tutty usually contains oxide of cadmium. The alloy consists of,

Copper,	100.
Cadmium,	84.2

The alloy of cobalt and cadmium has a good deal of resemblance to arsenical cobalt. Its colour is almost silver white. 100 parts of platinum combine with 117.3 of cadmium. Cadmium and mercury readily unite cold, into a fine silver white amalgam, of a granular texture, which may be crystallized in octohedrons. Its specific gravity is greater than that of mercury! It fuses at 167° F. It consists of,

Mercury,	100.
Cadmium,	27.78

Dr. Clarke found in 100 gr. of the fibrous silicate of zinc, of Derbyshire, about $\frac{6}{10}$ of a grain of sulphuret of cadmium, a result which agrees with the experiments of Dr. Wollaston and Mr. Children.*

Caffein. By adding muriate of tin to an infusion of unroasted coffee, M. Chenevix obtained a precipitate, which he washed and decomposed by sulphuretted hydrogen. The supernatant liquid contained a peculiar bitter principle, which occasioned a green precipitate in concentrated solutions of iron. When the liquid was evaporated to dryness, it was yellow and transparent, like horn. It did not attract moisture from the air but was soluble in water and alcohol. The solution had a pleasant bitter taste, and assumed with alkalis a garnet-red colour. It is almost as delicate a test of iron as infusion of galls is; yet gelatin occasions no precipitate with it.

Cajeput Oil. The volatile oil obtained from the leaves of the cajeput tree. Cajeputa officinarum, the Melaleuca Leucadendron of Linnæus. The tree which furnishes the cajeput oil is frequent on the mountains of Amboyna, and other Molucca islands. It is obtained by distillation from the dried leaves of the smaller of two varieties It is prepared in great quantities, especially in the island of Banda, and sent to Holland in copper flasks. As it comes to us, it is of a green colour, very limpid, lighter than water, of a strong smell, resembling camphor, and a strong pungent taste, like that of cardamons. It burns entirely away, without leaving any residuum. It is often adulterated with other essential oils, coloured with the resin of milfoil. In the genuine oil, the green colour depends on the presence of copper; for when rectified it is colourless.

Calamine. A native carbonate of zinc.

Calcareous Earth. See Lime.

* **Calcareous Spar.** Crystallized carbonate of lime. It occurs crystallized in more than 600 different forms, all having for their primitive form an obtuse rhomboid, with angles of 74° 55′ and 105° 5′. It occurs also massive, and in imitative shapes. Werner has given a comprehensive idea of the varieties of the crystals, by referring all the forms to the six-sided pyramid, the six-sided prism, and the three-sided prism, with their truncations. The colours of calc-spar are gray, yellow, red, green, and rarely blue. Vitreous lustre. Foliated fracture, with a threefold cleavage. Fragments rhomboidal. Transparent, or translucent. The transparent crystals refract double. It is less hard than fluor spar and is easily broken Sp. gr. 2.7. It consists of 43.6 carbonic acid, and 56.4 lime. It effervesces powerfully with acids. Some varieties are phosphorescent on hot coals. It is found in veins in all rocks, from granite to alluvial strata, and sometimes in strata between the beds of calcareous mountains. The rarest and most beautiful crystals are found in Derbyshire, but it exists in every part of the world.*

* **Calcedony.** A mineral so called from Calcedon in Asia Minor where it was found in ancient times. There are several subspecies: common calcedony, heliotrope, chrysoprase, plasma, onyx, sard, and sardonyx.

Common calcedony occurs in various shades of white, gray, yellow, brown, green, and blue. The blackish-brown appears, on looking through the mineral, to become a blood-red. It is found in nodules; botryoidal, stalactitical, bearing organic impressions, in veins, and also massive. Its fracture is even, sometimes flat conchoidal, or fine splintery. Semi-transparent, harder and tougher than flint. Sp. grav. 2.6. It is not fusible. It may be regarded as pure silica, with a minute portion of water. Very fine stalactitical specimens have been found in Trevascus mine in Cornwall. It occurs in the toadstone of Derbyshire, in the trap rocks of Fifeshire, of the Pentland-hills, Mull, Rum, Sky, and others of the Scotish Hebrides; likewise in Iceland, and the Ferro Islands. See the sub-species, under their respective titles.*

* **Calc Sinter.** Stalactitical carbonate of lime. It is found in pendulous conical rods or tubes, mamellated, massive, and in many imitative shapes. Fracture lamellar, or divergent fibrous. Lustre silky or pearly. Colours white, of various shades, yellow, brown, rarely green, passing into blue or red. Translucent—semihard—very brittle. Large stalactites are found in the grotto of Antiparos, the woodman's cave in the Hartz, the cave of Auxelle in France, in the cave of Castleton in Derbyshire, and Macalister cave in Sky. They are continually forming by the infiltration of carbonated lime-water, through the crevices of the roofs of caverns. Solid masses of stalactite have been called oriental alabaster. The irregular masses on the bottoms of caves have been called stalagmites.*

* **Calchantum.** Pliny's term for copperas.*

Calcination. The fixed residues of such matters as have undergone combustion are called cinders in common language, and calces, or now more commonly oxides, by chemists; and the operation, when considered with regard to these residues, is termed calcination. In this general way it has likewise been applied to bodies not really combustible, but only deprived of some of their principles by heat. Thus we hear of the calcination of chalk, to convert it into lime, by driving off its carbonic acid and water; of gypsum or plaster stone, of alum, of borax, and other saline bodies, by which they are deprived of their water of crystallization; of bones, which lose their volatile parts by this treatment; and of various other bodies. See Combustion and Oxidation.

* **Calcium.** The metallic basis of lime. Sir H. Davy, the discoverer of this metal, procured it by the process which he used for obtaining *barium;* which see. It was in such small quantities, that little could be said concerning its nature. It appeared brighter and whiter than either barium or strontium; and burned when gently heated, producing dry lime.

There is only one known combination of calcium and oxygen, which is the important substance called lime. The nature of this substance is proved by the phenomena of the combustion of calcium; the metal changing into the earth with the absorption of oxygen gas. When the amalgam of calcium is thrown into water, hydrogen gas is disengaged, and the water becomes a solution of lime. From the quantity of hydrogen evolved, compared with the quantity of lime formed in experiments of this kind,

M. Berzelius endeavoured to ascertain the proportion of oxygen in lime. The nature of lime may also be proved by analysis. When potassium in vapour is sent through the earth ignited to whiteness, the potassium was found by Sir H. Davy to become potash, while a dark gray substance of metallic splendour, which is calcium, either wholly or partially deprived of oxygen, is found imbedded in the potash, for it effervesces violently, and forms a solution of lime by the action of water.

Lime is usually obtained for chemical purposes, from marble of the whitest kind, or from calcareous spar, by long exposure to a strong red heat. It is a soft white substance, of specific gravity 2.3. It requires an intense degree of heat for its fusion; and has not hitherto been volatilized. Its taste is caustic, astringent and alkaline. It is soluble in 450 parts of water, according to Sir H. Davy; and in 760 parts, according to other chemists. The solubility is not increased by heat. If a little water only be sprinkled on new burnt lime, it is rapidly absorbed, with the evolution of much heat and vapour. This constitutes the phenomenon called slaking. The heat proceeds, according to Dr. Black's explanation, from the consolidation of the liquid water into the lime, forming a *hydrate*, as slaked lime is now called. It is a compound of 3.56 parts of lime, with 1.125 of water; or very nearly 3 to 1. This water may be expelled by a red heat, and therefore does not adhere to lime with the same energy as it does to barytes and strontites. Lime water is astringent and somewhat acrid to the taste. It renders vegetable blues green; the yellows brown; and restores to reddened litmus its usual purple. When lime water stands exposed to the air, it gradually attracts carbonic acid, and becomes an insoluble carbonate, while the water remains pure. If lime water be placed in a capsule under an exhausted receiver, which also encloses a saucer filled with concentrated sulphuric acid, the water will be gradually withdrawn from the lime, which will concrete into small six-sided prismatic crystals.

Berzelius attempted to determine the prime equivalent of calcium, from the proportion in which it combines with oxygen, to form lime; but his results can be regarded only as approximations, in consequence of the difficulties of the experiment. The prime equivalent of lime, or oxide of calcium, can be determined to rigid precision, by my instrument for analyzing the carbonates. By this means, I find, that 100 parts of carbonate of lime, consist of 43.60 carbonic acid + 56.4 lime; whence the prime equivalent proportions are, 2.75 acid + 3.562 base.

If a piece of phosphorus be put into the sealed end of a glass tube, the middle part of which is filled with bits of lime about the size of peas; and after the latter is ignited, if the former be driven through it in vapour, heating the end of the tube, a compound of a dark brown colour, called phosphuret of lime, will be formed. This probably consists of 1.5 phosphorus + 3.56 lime; but it has not been exactly analyzed. When thrown into water, phosphuretted hydrogen gas is disengaged in small bubbles, which explode in succession as they burst.

Sulphuret of lime is formed by fusing the constituents mixed together in a covered crucible. The mass is reddish coloured and very acrid. It deliquesces on exposure to air, and becomes of a greenish-yellow hue. When it is put into water, a hydroguretted sulphuret of lime is immediately formed. The same liquid compound may be directly made, by boiling a mixture of sulphur and lime in water. It acts corrosively on animal bodies, and is a powerful reagent in precipitating metals from their solutions. Solid sulphuret of lime probably consists of 2. sulphur + 3.56 lime.

When lime is heated strongly in contact with chlorine, oxygen is expelled, and the chlorine is absorbed. For every two parts in volume of chlorine that disappear, one of oxygen is obtained. When liquid muriate of lime is evaporated to dryness, and ignited, it forms the same substance, or chloride of calcium. It is a semitransparent crystalline substance; fusible at a strong red heat; a non-conductor of electricity; has a very bitter taste; rapidly absorbs water from the atmosphere; and is extremely soluble in water. (See Muriatic Acid). It consists of 2.56 calcium + 4.45 chlorine = 7.01. Chlorine combines also with oxide of calcium or lime, forming the very important substance used in bleaching, under the name of oxymuriate of lime; but which is more correctly called chloride of lime.

Several years ago I performed a series of laborious, and rather insalubrious experiments, synthetical and analytical, on chloride of lime; the results of some of which were detailed in a manuscript essay on alkalimetry, and other subjects connected with bleaching, submitted to Dr. Henry in 1816. Having since then been occupied in extending my new methods of chemical research, I have delayed publishing till my plans shall be completed. Meanwhile I shall observe, that slaked lime absorbs chlorine very greedily, though unslaked lime, at ordinary temperatures, condenses scarcely an appreciable quantity of the dry gas. Under a very trifling pressure, hydrate of lime is capable of condensing almost its own weight of chlorine; or 3.56 lime + 1.125 water = 4.685, combine with 4.45 chlorine. Hence, it is really a chloride of lime, and not a sub-bichloride, as Dr. Thomson and Mr. Dalton have hastily inferred from commercial samples, altered by carriage and keeping. And indeed, as it is not the interest of the manufacturer to make so rich and pure a compound, when he can get the market price for what contains only one-third or one-fourth the quantity of chlorine, it is absurd to assume a commercial article as the just chemical standard, or equivalent combination. In my first set of experiments, I took a certain weight of pure lime, slaked it, and saturated it with pure chlorine. I next ascertained, by analysis, the proportion of lime, water, and chlorine, that existed in the compound. The synthesis and analysis agreed very well. But the chloride slowly changes its nature from the disengagement of oxygen, by the superior affinity of the chlorine for the calcium. Hence, as well as from negligence or fraud in the manufacture, the chloride of lime is always mixed with more or less of the common muriate. For this reason, as well as for that assigned by M. Gay-Lussac, in his judicious critique on Dr. Thomson's paper on oxymuriate of lime, it is impossible to infer the bleaching power, or to analyze it, by using nitrate of silver. This test shows *strongest* in fact, when the power is *weakest*, or when the oxymuriate has passed into common muriate, to use the manufacturer's language. Nor is it possible to analyze the chloride with any precision, by exposing it to heat and measuring the oxygen expelled; because variable portions of chlorine are separated at the same time, in very uncertain states of combination. It is difficult to conceive how a chemist of Dr. Thomson's high reputation, should ever have pitched upon nitrate of silver to analyze the mingled chlorides of lime and calcium.

In performing the synthetic experiment, the hydrate of lime must be kept cool, otherwise the heat produced by the chemical union, is very apt to expel oxygen from the lime, and generate some chloride of calcium. Mr. Dalton advises the use of solution of copperas, to analyze the bleaching powder. He desires us to add it, till all the chlorine smell disappears, and to measure the quantity of copperas employed. I tried this method, and was nearly killed by it. The repeated and careful application of the nostrils to the mixture, and the inevitable inhalation of chlorine, evolved by the sulphate of iron, brought on a very painful and dangerous affection of the lungs.

There is usually a considerable quantity of unsaturated lime in the above powder; the amount of which is readily ascertained by digesting it in water, and filtering. It may be expected, that I should now give my own method of analysis; but the desire of verifying it by some further experiments of a new kind for which I have hitherto wanted leisure, induces me to suppress it for the present. Under LIME, some observations will be found on the uses of this substance.

If the liquid hydriodate of lime be evaporated to dryness, and gently heated, an iodide of calcium remains. It has not been applied to any use.*

* CALCTUFF. An alluvial formation of carbonate of lime, probably deposited from calcareous springs. It has a yellowish-gray colour; a dull lustre internally; a fine grained earthy fracture; is opaque, and usually marked with impressions of vegetable matter. Its specific gravity is nearly the same with that of water. It is soft, and easily cut or broken.*

* CALCULUS, *or* STONE. This name is generally given to all hard concretions, not bony, formed in the bodies of animals. Of these the most important, as giving rise to one of the most painful diseases incident to human nature, is the *urinary calculus*, or stone in the bladder. Different substances occasionally enter into the composition of this calculus, but the most usual is the lithic acid.

If we except Scheele's original observation concerning the uric or lithic acid, all the discoveries relating to urinary concretions are due to Dr. Wollaston; discoveries so curious and important, as alone are sufficient to entitle him to the admiration and gratitude of mankind. They have been fully verified by the subsequent researches of MM. Fourcroy, Vauquelin, and Brande, Drs. Henry, Marcet, and Prout. Dr. Marcet, in his late valuable essay on the chemical history and medical treatment of calculous disorders, arranges the concretions into nine species.

1. The lithic acid calculus.
2. The ammonia-magnesian phosphate calculus.
3. The bone earth calculus, or phosphate of lime.
4. The fusible calculus, a mixture of the 2d and 3d species.
5. The mulberry calculus, or oxalate of lime.
6. The cystic calculus; cystic oxide of Dr. Wollaston.
7. The alternating calculus, composed of alternate layers of different species.
8. The compound calculus, whose ingredients are so intimately mixed, as to be separable only by chemical analysis.
9. Calculus from the prostate gland, which, by Dr. Wollaston's researches, is proved to be phosphate of lime, not distinctly stratified, and tinged by the secretion of the prostate gland.

To the above Dr. Marcet has added two new sub-species. The first seems to have some resemblance to the cystic oxide, but it possesses also some marks of distinction. It forms a bright lemon-yellow residuum on evaporating its nitric acid solution, and is composed of laminæ. But the cystic oxide is not laminated, and it leaves a white residuum from the nitric acid solution. Though they are both soluble in acids as well as alkalis, yet the oxide is more so in acids than the new calculus, which has been called by Dr. Marcet, from its yellow residuum, *xanthic* oxide. Dr. Marcet's other new calculus, was found to possess the properties of the fibrin of the blood, of which it seems to be a deposite. He terms it *fibrinous* calculus.

Species I. Uric acid calculi. Dr Henry says, in his instructive paper on urinary and other morbid concretions, read before the Medical Society of London, March 2, 1819, that it has never yet occurred to him to examine calculi composed of this acid in a state of absolute purity. They contain about 9-10ths of the pure acid, along with urea, and an animal matter which is not gelatin, but of an albuminous nature. This must not, however, be regarded as a cement. The calculus is aggregated by the cohesive attraction of the lithic acid itself. The colour of lithic acid calculi is yellowish, or reddish-brown, resembling the appearance of wood. They have commonly a smooth polished surface, a lamellar or radiated structure, and consist of fine particles well compacted. Their sp. gravity varies from 1.3 to 1.8. They dissolve in alkaline lixivia, without evolving an ammoniacal odour, and exhale the smell of horn before the blow-pipe. The relative frequency of lithic acid calculi will be seen from the following statement. Of 150 examined by Mr. Brande, 16 were composed wholly of this acid, and almost all contained more or less of it. Fourcroy and Vauquelin found it in the greater number of 500 which they analyzed. All those examined by Scheele consisted of it alone; and 300 analyzed by Dr. Pearson, contained it in greater or smaller proportion. According to Dr. Henry's experience, it constitutes 10 urinary concretions out of 26, exclusive of the alternating calculi. And Mr. Brande lately states, that out of 58 cases of *kidney* calculi, 51 were lithic acid, 6 oxalic, and 1 cystic.

Species 2. Ammonia-magnesian phosphate. This calculus is white like chalk, is friable between the fingers, is often covered with dog-tooth crystals, and contains semi-crystalline layers. It is *insoluble* in alkalis, but soluble in nitric, muriatic, and acetic acids. According to Dr. Henry, the earthy phosphates, comprehending the 2d and 3d species, were to the whole number of concretions, in the ratio of 10 to 85. Mr. Brande justly observes, in the 16th number of his Journal, that the urine has at all times a tendency to deposite the triple phosphate, upon any body over which it passes. Hence drains by which urine is carried off, are often incrusted with its regular crystals; and in cases where extraneous bodies have got into the bladder, they have often in a very short time become considerably enlarged by deposition of the same substance. When this calculus, or those incrusted with its semi-crystalline particles are strongly heated before the blow-pipe, ammonia is evolved, and an imperfect fusion takes place. When a little of the calcareous phosphate is present, however, the concretion readily fuses. Calculi composed *entirely* of the ammonia-magnesian phosphate are very rare. Mr. Brande has seen only two. They were crystallized upon the surface, and their fracture was somewhat foliated. In its pure state, it is even rare as an incrustation. The powder of the ammonia-phosphate calculus has a brilliant white colour, a faint sweetish taste, and is somewhat soluble in water. Fourcroy and Vauquelin suppose the above deposites to result from incipient putrefaction of urine in the bladder. It is certain that the triple phosphate is copiously precipitated from urine in such circumstances out of the body.

Species 3. The bone earth calculus. Its surface according to Dr. Wollaston, is generally pale brown, smooth, and when sawed through, it appears of a laminated texture, easily separable into concentric crusts. Sometimes, also, each lamina is striated in a direction perpendicular to the surface, as from an assemblage of crystalline needles. It is difficult to fuse this calculus by the blow-pipe, but it dissolves readily in dilute muriatic acid, from which it is precipitable by ammonia. This species, as described by Fourcroy and Vauquelin, was white, without lustre, friable, staining the hands, paper, and cloth. It had much of a chalky appearance, and broke under the forceps, and was intimately mixed with a gelatinous matter, which is left in a membranous form, when the earthy salt is withdrawn by dilute muriatic acid. Dr. Henry says that he has never been able to recognize a calculus of pure phosphate of lime, in any of the collections which he has examined; nor did he ever find the preceding species in a pure state, though a calculus in Mr. White's collection contained more than 90 per cent of ammonia-magnesian phosphate.

Species 4. The fusible calculus. This is a very friable concretion, of a white colour, resembling chalk in appearance and texture; it often breaks into layers, and exhibits a glittering appearance internally, from intermixture of the crystals of triple phosphate. Sp. grav. from 1.14 to 1.47. Soluble in dilute muriatic and nitric acids, but not in alkaline lixivia. The nucleus is generally lithic acid. In 4 instances only out of 187, did Dr. Henry find the calculus composed throughout of the earthy phosphates. The analysis of fusible calculus is easily performed by distilled vinegar, which at a gentle heat dissolves the ammonia-magnesian phosphate, but not the phosphate of lime; the latter may be taken up by dilute muriatic acid. The lithic acid present will remain, and may be recognized by its solubility in the water of pure potash or soda. Or the lithic acid may, in the first instance, be removed by the alkali, which expels the ammonia, and leaves the phosphate of magnesia and lime.

Species 5. The mulberry calculus. Its surface is rough and tuberculated; colour deep reddish-brown. Sometimes it is pale brown, of a crytalline texture, and covered with flat octohedral crystals. This calculus has commonly the density and hardness of ivory, a sp. grav. from 1.4 to 1.98, and exhales the odour of semen when sawed. A moderate red heat converts it into carbonate of lime. It does not dissolve in alkaline lixivia, but slowly and with difficulty in acids. When the oxalate of lime is voided directly after leaving the kidney, it is of a grayish-brown colour, composed of small cohering spherules, sometimes with a polished surface resembling hempseed. They are easily recognized by their insolubility in muriatic acid, and their swelling up and passing into pure lime before the blow-pipe. Mulberry calculi contain always an admixture of other substances besides oxalate of lime. These are, uric acid, phosphate of lime, and animal matter in dark flocculi. The colouring matter of these calculi is probably effused blood. Dr. Henry rates the frequency of this species at 1 in 17 of the whole which he has compared; and out of 187 calculi, he found that 17 were formed round *nuclei* of oxalate of lime.

Species 6. The cystic-oxide calculus. It resembles a little the triple phosphate, or more exactly magnesian limestone. It is somewhat tough when cut, and has a peculiar greasy lustre. Its usual colour is pale brown, bordering on straw-yellow; and its texture is irregularly crystalline. It unites in solution with acids and alkalis, crystallizing with both. Alcohol precipitates it from nitric acid. It does not become red with nitric acid, and it has no effect upon vegetable blues. Neither water, Alcohol, nor ether dissolves it. It is decomposed by heat into carbonate of ammonia and oil, leaving a minute residuum of phosphate of lime. This concretion is of very rare occurrence. Dr. Henry states its frequency to the whole, as 10 to 985. In two which he examined, the nucleus was the same substance with the rest of the concretion; and in a third, the nucleus of an uric acid calculus was a small spherule of cystic oxide. Hence, as Dr. Marcet has remarked, this oxide appears to be in reality the production of the kidneys, and not, as its name would import, to be generated in the bladder. It might be called with propriety *renal* oxide, if its eminent discover should think fit.

Species 7. The *alternating calculus*. The surface of this calculus is usually white like chalk, and friable or semi-crystalline, according as the exterior coat is the calcareous or ammonia-magnesian phosphate. They are frequently of a large size, and contain a nucleus of lithic acid. Sometimes the two phosphates form alternate layers round the nucleus. The above are the most common alternating calculi; next are those of oxalate of lime with phosphates; then oxalate of lime with lithic acid; and lastly, those in which the three substances alternate. The alternating, taken all together, occur in 10 out of 25, in Dr. Henry's list; the lithic acid with phosphates as 10 to 48; the oxalate of lime with phosphates, as 10 to 116; the oxalate of lime with lithic acid, as 10 to 170; the oxalate of lime, with lithic acid and phosphates, as 10 to 265.

Species 8. The compound calculus. This consists of a mixture of lithic acid with the phosphates in variable proportions, and is consequently variable in its appearance. Sometimes the alternating layers are so thin as to be undistinguishable by the eye, when their nature can be determined only by chemical analysis. This species, in Dr. Henry's list, forms 10 in 235. About 1-40th of the calculi examined by Fourcroy and Vauquelin were compound.

Species 9. has been already described.

In almost all calculi, a central nucleus may be discovered, sufficiently small to have descended through the ureters into the bladder. The disease of stone is to be considered, therefore, essentially and originally as belonging to the kidneys. Its increase in the bladder may be occasioned, either by exposure to urine that contains an excess of the same ingredient as that composing the nucleus, in which case it will be uniformly constituted throughout; or if the morbid nucleus deposite should cease, the concretion will then acquire a coating of the earthy phosphates. It becomes, therefore, highly important to ascertain the nature of the most predominant nucleus. Out of 187 calculi examined by Dr. Henry, 17 were formed round nuclei of oxalate of lime; 3 round nuclei of cystic oxide; 4 round nuclei of the earthy phosphates; 2 round extraneous substances; and in 3 the nucleus was replaced by a small cavity, occasioned probably by the shrinking of some animal matter, round which the ingredients of the calculi (fusible) had been deposited. Rau has shown by experiment, that pus may form the nucleus of an urinary concretion. The remaining 158 calculi of Dr. Henry's list, had central nuclei composed chiefly of lithic acid. It appears also, that in a very great majority of the cases referred to by him, the disposition to secrete an excess of lithic acid has been the essential cause of the origin of stone. Hence it becomes a matter of great importance to inquire, what are the circumstances which contribute to its excessive production, and to ascertain by what plan of diet and medicine this morbid action of the kidneys may best be obviated or removed. A calculus in Mr. White's collection had for its nucleus a fragment of a bougie, that had slipped into the bladder. It belonged to the fusible species, consisting of,

20	phosphate of lime
60	ammonia-magnesian phosphate
10	lithic acid
10	animal matter
100	

In some instances, though these are comparatively very few, a morbid secretion of the earthy phosphates in excess, is the cause of the formation of stone. Dr. Henry relates the case of a gentleman, who, during paroxysms of gravel, preceded by severe sickness and vomiting, voided urine as opaque as milk, which deposited a great quantity of an impalpable powder, consisting of the calcareous and triple phosphate in nearly equal proportions. The weight of the body was rapidly reduced from 188 to 100 pounds, apparently by the abstraction of the earth of his bones; for there was no emaciation of the muscles corresponding to the above diminution.

The first rational views on the treatment of calculous disorders, were given by Dr. Wollaston. These have been followed up lately by some very judicious observations of Mr. Brande, in the 12th, 15th, and 16th numbers of his Journal; and also by Dr. Marcet, in his excellent treatise already referred to. Of the many substances contained in human urine, there are rarely more than three which constitute gravel; viz. calcareous phosphate, ammonia-magnesian phosphate, and lithic acid. The former two form a white sediment; the latter a red or brown. The urine is always an acidulous secretion. Since by this excess of acid, the earthy salts, or white matter, are held in solution, whatever disorder of the system, or impropriety of food and medicine, diminishes that acid excess, favours the formation of white deposite. The internal use of acids was shown by Dr. Wollaston, to be the appropriate remedy in this case.

White gravel is frequently symptomatic of disordered digestion, arising from excess in eating or drinking; and it is often produced by too farinaceous a diet. It is also occasioned by the indiscreet use of magnesia, soda water, or alkaline medicines in general. Medical practitioners, as well as their patients, ignorant of chemistry, have often committed fatal mistakes, by considering the white gravel, passed on the administration of alkaline medicines, as the dissolution of the calculus itself; and have hence pushed a practice, which has rapidly increased the size of the stone. Magnesia, in many cases, acts more injuriously than alkali, in precipitating insoluble phosphate from the urine. The acids of urine, which, by their excess, hold the earths in solution, are the phosphoric, lithic, and carbonic. Mr. Brande has uniformly obtained the latter acid, by placing urine under an exhausted receiver; and he has formed carbonate of barytes, by dropping barytes water into urine recently voided.

The appearance of white sand does not seem deserving of much attention, where it is merely occasional, following indigestion brought on by an accidental excess. But if it invariably follows meals, and if it be observed in the urine, not as a mere deposite, but at the time the last drops are voided, it becomes a matter of importance, as the forerunner of other and serious forms of the disorder. It has been sometimes viewed as the *effect* of irritable bladder, where it was in reality the *cause*. Acids are the proper remedy, and unless some peculiar tonic effect be sought for in sulphuric acid, the vegetable acids ought to be preferred. Tartar, or its acid, may be prescribed with advantage, but the best medicine is citric acid, in daily doses of from 5 to 30 grains. Persons returning from warm climates, with dyspeptic and hepatic disorders, often void this white gravel, for which they have recourse to empyrical solvents, for the most part alkaline, and are deeply injured. They ought to adopt an acidulous diet, abstaining from soda water, alkalis, malt liquor, madeira and port; to eat salads with acid fruits; and if habit requires it, a glass of cyder, champagne or claret, but the less of these fermented liquors the better. An effervescing draught is often very beneficial, made by dissolving 30 grains of bicarbonate of potash, and 20 of citric acid, in separate tea cups of water, mixing the solution in a large tumbler, and drinking the whole during the effervescence. This dose may be repeated 3 or 4 times a-day. The carbonic acid of the above medicine enters the circulation, and passing off by the bladder, is useful in retaining, particularly, the triple phosphate in solution, as was first pointed out by Dr. Wollaston. The bowels should be kept regular by medicine and moderate exercise. The febrile affections of children are frequently attended by an apparently formidable deposite of white sand in the urine. A dose of calomel will generally carry off both the fever and the sand. Air, exercise, bark, bitters, mineral tonics, are in like manner often successful in removing the urinary complaints of grown up persons.

In considering the red gravel, it is necessary to distinguish between those cases in which the sand is actually voided, and those in which it is deposited, after some hours, from originally limpid urine. In the first, the sabulous appearance is an alarming indication of a tendency to form calculi; in the second, it is often merely a fleeting symptom of indigestion. Should it frequently recur, however, it is not to be disregarded.

Bicarbonate of potash or soda is the proper remedy for the red sand, or lithic acid deposite. The alkali may often be beneficially combined with opium. Ammonia, or its crystallized carbonate, may be resorted to with advantage, where symptoms of indigestion are brought on by the other alkalis; and particularly in red gravel connected with gout; in which the joints and kidneys are affected by turns. Where potash and soda have been so long employed as to disagree with the stomach, to create nausea, flatulency, a sense of weight, pain and other symptoms of indigestion, magnesia may be prescribed with the best effects. The tendency which it has to accumulate in dangerous quantities in the intestines, and to form a white sediment in urine, calls on the practitioner to look minutely after its administration. It should be occasionally alternated with other laxative medicines. Magnesia dissolved in carbonic acid, as Mr. Scheweppe used to prepare it many years ago, by the direction of Mr. Brande, is an elegant form of exhibiting this remedy.

Care must be had not to push the alkaline medicines too far, lest they give rise to the deposition of earthy phosphates in the urine.

Cases occur in which the sabulous deposite consists of a mixture of lithic acid with the phosphates. The sediment of urine in inflammatory disorders is sometimes of this nature; and of those persons who habitually indulge in excess of wine; and also of those who, labouring under hepatic affections, secrete much albumen in their urine. Purges, tonics, and nitric acid, which is the solvent of both the above sabulous matters, are the appropriate remedies. The best diet for patients labouring under the lithic deposite, is a vegetable. Dr. Wollaston's fine observation, that the excrement of birds fed solely upon animal matter, is in a great measure lithic acid, and the curious fact since ascertained, that the excrement of the boa constrictor, fed also entirely on animals, is pure lithic acid, concur in giving force to the above dietetic prescription. A week's abstinence from animal food has been known to relieve a fit of lithic acid gravel, where the alkalis were of little avail. But we must not carry the vegetable system so far as to produce flatulency and indigestion.

Such are the principal circumstances connected with the disease of gravel in its incipient or sabulous state. The calculi formed in the kidneys are, as we have said above, either lithic, oxalic, or cystic; and very rarely indeed of the phosphate species. An aqueous regimen, moderate exercise on horseback when not accompanied with much irritation, cold bathing, and mild aperients, along with the appropriate chemical medicines, must be prescribed in kidney cases. These are particularly requisite immediately after acute pain in the region of the ureter, and inflammatory symptoms have led to the belief that a nucleus has descended into the bladder. Purges, diuretics, and diluents, ought to be liberally enjoined. A large quantity of mucus streaked with blood, or of a purulent aspect, and hæmorrhagy, are frequent symptoms of the passage of the stone into the bladder

When a stone has once lodged in the bladder, and increased there to such a size as no longer to be capable of passing through the urethra, it is generally allowed, by all who have candidly considered the subject, and who are qualified by experience to be judges, that the stone can never again be dissolved; and although it is possible that it may become so loosened in its texture, as to be voided piecemeal, or gradually to crumble away, the event is so rare as to be barely probable.

By examining collections of calculi we learn, that in by far the greater number of cases, a nucleus of lithic acid is enveloped in a crust of the phosphates. Our endeavours must therefore be directed towards reducing the excess of lithic acid in the urine to its natural standard; or, on the other hand, to lessen the tendency to the deposition of the phosphates. The urine must be submitted to chemical examination, and a suitable course of diet and medicines prescribed. But the chemical remedies must be regulated nicely, so as to hit the happy equilibrium, in which no deposite will be formed. Here is a powerful call on the physicians and surgeons to make themselves thoroughly versant in chemical science; for they will otherwise commit the most dangerous blunders in calculous complaints.

"The idea of dissolving a calculus of uric acid in the bladder by the internal use of the caustic alkalis," says Mr. Brande, "appears too absurd to merit serious refutation." In respect to the phosphates, it seems possible, by keeping up an unusual acidity in the urine, so far to soften a crust of the calculus, as to make it crumble down, or admit of being abraded by the sound; but this is the utmost that can be looked for; and the lithic nucleus will still remain. "These considerations," adds Mr. Brande, "independent of more urgent reasons, show the futility of attempting the solution of a stone of the bladder by the injection of acid and alkaline solutions. In respect to the alkalis, if sufficiently strong to act upon the uric crust of the calculus, they would certainly injure the coats of the bladder; they would otherwise become inactive by combination with the acids of the urine, and they would form a dangerous precipitate from the same cause."—"It therefore appears to me, that

Fourcroy, and others who have advised the plan of injection, have thought little of all these obstacles to success, and have regarded the bladder as a lifeless receptacle into which, as into an India rubber bottle, almost any solvent might be injected with impunity."—*Journal of Science*, vol. vii, p. 216.

I have judged it an imperative duty to insert the above cautions, from an eminent chemist who has studied this subject in its medical relations, lest the medical student, misled by Dr. Thomson's favourable transcript of the injection scheme, might be hurried into very dangerous practice.

It does not appear that the peculiarities of water in different districts, have any influence upon the production of calculous disorders. Dr. Wollaston's discovery of the analogy between urinary and gouty concretions, has led to the trial in gravel of the *vinum colchici*, the specific for gout. By a note to Mr. Brande's dissertation we learn, that benefit has been derived from it in a case of red gravel.

Dr. Henry confirms the above precepts in the following decided language. "These cases, and others of the same kind, which I think it unnecessary to mention, tend to discourage all attempts to dissolve a stone supposed to consist of uric acid, after it has attained considerable size in the bladder; all that can be effected under such circumstances by alkaline medicines appears, as Mr. Brande has remarked, to be the precipitating upon it a coating of the earthy phosphates from the urine, a sort of concretion which, as has been observed by various practical writers, increases much more rapidly than that consisting of uric acid only. The same unfavourable inference may be drawn also from the dissections of those persons in whom a stone was supposed to be dissolved by alkaline medicines; for in these instances it has been found either encysted, or placed out of the reach of the sound by an enlargement of the prostate gland.*

The urinary calculus of a dog, examined by Dr. Pearson, was found to consist principally of the phosphates of lime and ammonia, with animal matter. Several taken from horses, were of a similar composition. One of a rabbit consisted chiefly of carbonate of lime and animal matter, with perhaps a little phosphoric acid. A quantity of sabulous matter, neither crystallized nor concrete, is sometimes found in the bladder of the horse: in one instance there were nearly 45 pounds. These appear to consist of carbonate of lime and animal matter. A calculus of a cat gave Fourcroy three parts of carbonate, and one of phosphate of lime. That of a pig, according to Bertholdi, was phosphate of lime.

The renal calculus in man appears to be of the same nature as the urinary. In that of the horse, Fourcroy found 3 parts of carbonate, and one of phosphate of lime. Dr. Pearson, in one instance, carbonate of lime, and animal matter; in two others, phosphates of lime and ammonia, with animal matter.

Arthritic calculi, or those formed in the joints of gouty persons, were once supposed to be carbonate of lime, whence they were called chalkstones; afterward it was supposed that they were phosphate of lime; but Dr. Wollaston has shown, that they are lithate of soda. The calculi found sometimes in the pineal, prostate, salivary, and bronchial glands, in the pancreas, in the corpora cavernosa penis, and between the muscles, as well as the tartar, as it is called, that encrusts the teeth, appear to be phosphate of lime. Dr. Crompton, however, examined a calculus taken from the lungs of a deceased soldier, which consisted of lime 45, carbonic acid 37, albumen and water 18. It was very hard, irregularly spheroidal, and measured about 6½ inches in circumference.

For the biliary calculi, see Gall. Those called *bezoars* have been already noticed under that article.

It has been observed, that the lithic acid, which constitutes the chief part of most human urinary calculi, and abounds in the arthritic, has been found in no phytivorous animal; and hence has been deduced a practical inference, that abstinence from animal food would prevent their formation. But we are inclined to think this conclusion too hasty. The cat is carnivorous; but it appeared above, that the calculus of that animal is equally destitute of lithic acid. If, therefore, we would form any deduction with respect to regimen, we must look for something used by man, exclusively of all other animals; and this is obviously found in fermented liquors, but apparently in nothing else: and this practical inference is sanctioned by the most respectable medical authorities.

On Caloric. *By Dr. Ure.*

* **Caloric.** The Agent to which the phenomena of heat and combustion are ascribed. This is hypothetically regarded as a fluid, of inappreciable tenuity, whose particles are endowed with indefinite idio-repulsive powers, and which by their distribution in various proportions among the particles of ponderable matter, modify cohesive attraction, giving birth to the three general forms of gaseous, liquid, and solid.

Many eminent philosophers, however, have doubted the separate entity of a calorific matter, and have adduced evidence to show that the phenomena might be rather referred to a vibratory or intestinal motion of the particles of common matter. The most distinguished advocate of this opinion in modern times is Sir H. Davy, the usual justness and profundity of whose views entitle them to deference. The following sketch of his ideas on this intricate subject, though it graduates perhaps into the poetry of science, cannot fail to increase our admiration of his genius, and to inculcate moderation on the partisans of the opposite doctrine.

"Calorific repulsion has been accounted for by supposing a subtile fluid capable of combining with bodies, and of separating their parts from each other, which has been named the *matter of heat or caloric*.

"Many of the phenomena admit of a happy explanation on this idea, such as the cold produced during the conversion of solids into fluids or gases, and the increase of temperature connected with the condensation of gases and fluids." In the former case we say the matter of heat is absorbed or combined; in the latter it is extruded or disengaged from combination. "But there are other facts which are not so easily reconciled to the opinion. Such are the production of heat by friction and percussion; and some of the chemical changes which have been just referred to." These are the violent heat produced in the explosion of gunpowder, where a large quantity of aeriform matter is disengaged; and the fire which appears in the decomposition of the euchlorine gas, or protoxide of chlorine, though the resulting gases occupy a greater volume.

"When the temperature of bodies is raised by friction, there seems to be no diminution of their capacities, using the word in its common sense; and in many chemical changes, connected with an increase of temperature, there appears to be likewise an increase of capacity. A piece of iron made red-hot by hammering, cannot be strongly heated a second time by the same means, unless it has been previously introduced into a fire. This fact has been explained by supposing that the fluid of heat has been pressed out of it, by the percussion, which is recovered in the fire; but this is a very rude mechanical idea: the arrangements of its parts are altered by hammering in this way, and it is rendered brittle. By a moderate degree of friction, as would appear from Rumford's experiments, the same piece of metal may be kept hot for any length of time; so that if heat be pressed out, the quantity must be inexhaustible. When any body is cooled, it occupies a smaller volume than before; it is evident therefore that its parts must have approached to each other; when the body is expanded by heat, it is equally evident that its parts must have separated from each other. The immediate cause of the phenomena of heat, then, is motion, and the laws of its communication are precisely the same as the laws of the communication of motion." Since all matter may be made to fill a smaller volume by cooling, it is evident that the particles of matter must have space between them; and since every body can communicate the power of expansion to a body of a lower temperature, that is, can give an expansive motion to its particles, it is a probable inference that its own particles are possessed of motion; but as there is no change in the position of its parts as long as its temperature is uniform, the motion, if it exist, must be a vibratory or undulatory motion, or a motion of the particles round their axes, or a motion of particles round each other.

"It seems possible to account for all the phenomena of heat, if it be supposed that in solids the particles are in a constant state of vibratory motion, the particles of the hottest bodies moving with the greatest velocity, and through the greatest space; that in liquids and elastic fluids, besides the vibratory motion, which must be conceived greatest in the last, the particles have a motion round their own axes, with different velocities, the particles of elastic fluids moving with the greatest quickness; and that in ethereal substances," the particles move round their own axes, and separate from each other, penetrating in right lines through space. Temperature may be conceived to depend upon the velocities of the vibrations; increase of capacity on the motion being performed in greater space; and the diminution of temperature, during the conversion of solids into fluids or gases, may be explained on the idea of the loss of vibratory motion, in consequence of the revolution of particles round their axes, at the moment when the body becomes liquid or aeriform; or from the loss of rapidity of vibration, in consequence of the motion of the particles through greater space.

"If a specific fluid of heat be admitted, it must be supposed liable to most of the affections which the particles of common matter are assumed to possess, to account for the phenomena; such as losing its motion when combining with bodies, producing motion when transmitted from one body to another, and gaining projectile motion when passing into free space; so that many hypotheses must be adopted to account for its agency, which renders this view of the subject less simple than the other. Very delicate experiments have been made, which show that bodies, when heated, do not increase in weight. This, as far as it goes, is an evidence against a subtile elastic fluid, producing the calorific expansion; but it cannot be considered as decisive, on account of the imperfection of our instruments. A cubical inch of inflammable air requires a good balance to ascertain that it has any sensible weight, and a substance bearing the same relation to this, that this bears to platinum, could not perhaps be weighed by any method in our possession."†

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†This view of the subject is to me unsatisfactory. It is true that the idea of heat

It has been supposed, on the other hand, that the observations of Sir Wm. Herschel on the calorific rays which accompany those of light in the solar beam, afford decisive

being motion, is sanctioned by Newton, as well as by the illustrious chemist above named. But the former adopted his opinion at a time, when the existence of heat in a latent state was as yet unsuspected, and when many phenomena unfavourable to the notion he suggested were unknown. It is fully established in mechanics, that when a body in motion is blended with and thus made to communicate motion to another body, previously at rest, or moving slower, the velocity of the compound mass after the impact will be found, by multiplying the weight of each body, by its respective velocity, and dividing the sum of the products, by the aggregate weight of both bodies. Of course it will be more than a mean or less than a mean, accordingly as the quicker body was lighter or heavier than the other. Now according to Sir Humphrey Davy, the particles of substances which are unequally heated are moving with unequal degrees of velocity; of course when they are reduced by contact to a common temperature, the heat, or what is the same (in his view), the velocity of the movements of their particles, ought to be found by multiplying the heat of each by its weight and dividing the sum of the product by the aggregate weight. Hence if equal weights of matter be mixed, the temperature ought to be a mean; and if equal bulks, it ought to be as much nearer the previous temperature of the heavier substance as the weight of the latter is greater; but the opposite is in most instances true. When equiponderant quantities of mercury and water are mixed at different temperatures, the result is such as might be expected from the mixture of the water, were it three times heavier; so much nearer to the previous heat of the water, is the consequent temperature. It may be said that this motion is not measurable upon mechanical principles. How then, I ask does it produce mechanical effects? These must be produced by the force of the vibrations, which are by the hypothesis mechanical: for whatever laws hold good in relation to moving matter in mass, must operate in regard to each particle of that matter; the effect of the former, can only be a multiple of that of the latter. Indeed, one of Sir Humphrey Davy's reasons for thinking heat to consist of corpuscular motions is that mechanical attrition generates it. Surely then a motion, produced by mechanical means, and which produces mechanical effects, may be estimated on mechanical principles.

In the case cited above, the power of reciprocal communication of heat in two fluids, is shown to be inconsistent with the views of this ingenious theorist. If we compare the same power in solids, the result will be equally objectionable. Thus the heating power of glass being 443, that of an equal bulk of lead will be 487, though so many times heavier; and if equal weights be compared, the effect of the glass, will be four times greater than that of the lead. If it be said, that the movements of the denser matter are made in less space and therefore require less motion, I answer that if they be made with equal velocity, they must go through equal space in the same time, their alternations being more frequent. And if they be not made with the same velocity, they could not communicate to matter of a lighter kind, a heat equally great; since agreeably to experience no superiority of weight will enable a body, acting directly on another to produce in it a motion quicker than its own. Consistently with this doctrine, the particles of an aeriform fluid, when they oppose a mechanical resistance, do it by aid of a certain movement, which causes them effectively to occupy a greater space than when at rest. It is true, a body, by moving backwards and forwards, may keep off other bodies from the space in which it moves. Thus let a weight be partially counterbalanced by means of a scale beam, so that if left to itself it would descend gently. Place exactly under it another equally solid mass, on which the weight would fall if unobstructed. If between the two bodies thus situated, a third be caused to undergo an alternate motion, it may keep the upper weight from descending, provided the force with which the latter descends, be no greater than that of the movement in the interposed mass, and the latter acts with such celerity, that between each stroke the time be too small for the weight to move any sensible distance. Here then we have a case analagous to that supposed, in which the alternate movements or vibrations of matter enable it to preserve to itself a greater space in opposition to a force impressed; and it must be evident that lengthening or shortening the extent of the vibrations of the interposed body, provided they are made in the same time, will increase or diminish the space apparently occupied by it, as the volume of substances is affected by an increase or reduction of heat. It ought however to be recollected that in the case we have imagined, there is a constant expenditure of momentum to compensate for that generated in the weight by gravity, during each vibration. In the vibrations conceived to constitute heat, there is no generating power to make up for this loss. A body preserves the expansion communicated by heat in vacuo, where, insulated from all other matter, the only momentum, by which the vibrations of its particles can evidence of the materiality of caloric, or at least place the proof of its existence and that of light, on the same foundation. That celebrated astronomer discovered that when similar thermometers were placed in the different parts of the solar beam, decomposed by the prism into the primitive colours, they indicated different temperatures. He estimates the power of heating in the red rays, to be to that of the green rays, as 55, to 26, and to that of the violet rays as 55 to 16. And in a space beyond the red rays, where there is no visible light, the increase of temperature is greatest of all. Thus, a thermometer in the full red ray rose 7° Fahr. in ten minutes; beyond the confines of the coloured beam entirely, it rose in an equal time 9°.

These experiments were repeated by Sir H. Englefield with similar results. Mr. Berard, however, came to a somewhat different conclusion. To render his experiments more certain, and their effects more sensible, this ingenious philosopher availed himself of the *heliostat*, an instrument by which the sunbeam can be steadily directed to one spot during the whole of its diurnal period. He decomposed by a prism the sunbeam, reflected from the mirror of the heliostat, and placed a sensible thermometer in each of the seven coloured rays. The calorific faculty was found to increase progressively from the violet to the red portion of the spectrum, in which the *maximum* heat existed, and *not* beyond it, in the unilluminated space. The greatest rise in the thermometer took place, while its bulb was still entirely covered by the last red rays; and it was observed progressively to sink as the bulb entered into the dark. Finally, on placing the bulb quite

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be supported, must have been received before its being thus situated. If we pour mercury into a glass tube shaped like a shepherd's crook, the hook being downwards, the fluid will be prevented from occupying that part of the tube where the air is in such position as not to escape. In this case, according to the hypothesis in question, the mercury is prevented from entering the space the air occupies, by a series of impalpable gyratory movements; so that the collision of the aerial particles against each other, causes each to occupy a larger share of space in the manner above illustrated by the descending weight and interposed body. The analogy will be greater, if we suppose a row of interposed bodies alternately striking against each other, and the descending weight; or we may imagine a vibration in all the particles of the interposed mass, equal in aggregate extent and force to that of the whole, when performing a common movement. If the aggregate extent of the vibration of the particles very much exceed that which when performed in mass would be necessary to preserve a certain space, it may be supposed productive of a substance like the air by which the mercury is resisted. But whence is the momentum adequate in such rare media to resist a pressure of a fluid so heavy as mercury, which in this case performs a part similar to that of the weight, cited for the purpose of illustration? If it be said that the mercury and glass being at the same temperature as the air, the particles of these substances vibrate in a manner to keep up the aerial pulsations; I ask, when the experiment is tried in an exhausted receiver, what is to supply momentum to the mercury and glass? There is no small difficulty in conceiving under the most favourable circumstances, that a species of motion, that exists according to the hypothesis as the cause of expansion in a heated solid, should cause a motion productive of fluidity or vaporization, as when by means of a hot iron, we convert ice into water, and water into vapour.

How inconceivable is it that the iron boiler of a steam engine should give to the particles of water, a motion so totally different from any it can itself possess, and at the same time capable of such wonderful effects, as are produced by the agency of steam. Is it to be imagined that in particles whose weight does not exceed a few ounces, sufficient momentum can be accumulated to move as many tons? There appears to me another very serious obstacle to this explanation of the nature of heat. How are we to account for its radiation in vacuo, which the distinguished advocate of the hypothesis has himself shown to ensue? There can be no motion without matter. To surmount this difficulty, he calls up a suggestion of Newton's, that the calorific vibrations of matter may send off radiant particles, which lose their own momentum in communicating vibrations to bodies remote from those, whence they emanate. Thus according to Sir Humphrey, there is radiant matter producing heat, and radiant matter producing light. Now, the only serious objection made by him to the doctrine which considers heat as material, will apply equally against the existence of material calorific emanations. That the cannon, heated by friction in the noted experiment of Rumford, would have radiated as well as if heated in any other way, there can, I think, be no doubt; and as well in vacuo, as the heat excited by Sir Humphrey in a similar situation. That its emission in this way would have been as inexhaustible as by the conducting process cannot be questioned. Why then is it not as easy to have an inexhaustible supply of heat as a material substance, as to have an inexhaustible supply of radiant matter, communicating the vibrations in which he represents heat to consist?

out of the visible spectrum, where Herschel fixed the maximum of heat, the elevation of its temperature above the ambient air was found, by M. Berard, to be only one-fifth of what it was in the extreme red ray. He afterwards made similar experiments on the double spectrum produced by *Iceland* crystal, and also on polarized light, and he found in both cases that the calorific principle accompanied the luminous molecules; and that in the positions where light ceased to be reflected, heat also disappeared.

Newton has shown that the different refrangibility of the rays of light may be explained by supposing them composed of particles differing in size, the largest being at the red, and the smallest at the violet extremity of the spectrum. The same great man has put the query, Whether light and common matter are not convertible into each other? and adopting the idea that the phenomena of sensible heat depend upon vibrations of the particles of bodies, supposes that a certain intensity of vibrations may send off particles into free space; and that particles in rapid motion in right lines, in losing their own motion, may communicate a vibratory motion to the particles of terrestrial bodies. In this way we can readily conceive how the red rays should impinge most forcibly, and therefore excite the greatest degree of heat.

Enough has now been said to show how little room there is to pronounce dogmatic decisions on the abstract nature of heat. If the essence of the cause be still involved in mystery, many of its properties and effects have been ascertained, and skilfully applied to the cultivation of science and the uses of life.†

We shall consider them in the following order:

1. Of the measure of temperature.
2. Of the distribution of heat.
3. Of the general habitudes of heat with the different forms of matter.

It will be convenient to make use of the popular language, and to speak of heat as existing in bodies in greater or smaller quantities, without meaning thereby to decide on the question of its nature.

1. Of the measure of temperature.

If a rod or ring of metal of considerable size, which is fitted to an oblong or circular guage in its ordinary state, be moderately heated, it will be found, on applying it to the cool guage, to have enlarged its dimensions. It is thus that coachmakers enlarge their strong iron rims, so as to make them embrace and firmly bind, by their retraction when cooled, the wooden frame-work of their wheels.

Ample experience has proved, that bodies, by being progressively heated, progressively increase in bulk. On this principle are constructed the various instruments for measuring temperature. If the body selected for indicating, by its increase of bulk, the increase of heat, suffered equal expansions by equal increments of the calorific power, then the instrument would be perfect, and we should have a just thermometer, or pyrometer. But it is very doubtful whether any substance, solid, liquid, or aeriform, preserves this equable relation, between its increase of volume and increase of heat. The following quotation from a paper which the Royal Society did me the honour to publish in their Transactions for 1818, conveys my notions on this subject:

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† We see the same matter, at different times, rendered self-attractive, or self-repellent; now cohering in the solid form with great tenacity, and now flying apart with explosive violence in the state of vapour. Hence the existence, in nature, of two opposite kinds of reaction, between particles, is self evident. There can be no property, without matter, in which it may be inherent. Nothing can have no property. The question then is, whether these opposite properties can belong to the same particles. Is it not evident, that the same particles cannot, at the same time, be self-repellent, and self-attractive? Suppose them to be so, one or the other must predominate, and in that case we should not perceive the existence of the other. It would be useless, and the particles would in effect, possess the predominant property alone, whether attraction or repulsion. If the properties were equal in power, they would annihilate each other, and the matter would be, as if void of either property. There must, therefore, be a matter, in which the self-repellent power resides, as well as matter in which attraction resides.

There must also be as many kinds of matter, as there are kinds of repulsion, of which the affinities, means of production, or laws of communication are different. Hence I do firmly believe in the existence of material fluids, severally producing the phenomena of heat, light and electricity. Substances, endowed with attraction, make themselves known to us, by that species of this power, which we call gravitation, by which they are drawn towards the earth, and are therefore heavy and called ponderable; by their resistance to our bodies, producing the sensation of feeling or touch; and by the vibrations or movements in other matter, affecting the ear with sounds, and the eye by a modified reflection of light. Where we perceive none of these usual concomitants of matter, we are prone to infer its absence. Hence ignorant people have no idea of air, except in the state of wind; and when even in a quiescent state designate it by this word. But that the principles, the existence of which has been demonstrated, should not be thus perceived, is far from being a reason for doubting their existence. A very slight attention to their qualities will make it evident, that they could not produce any of the effects, by which the existence of matter in its ordinary form is recognized. The self-repellent property renders it impossible that they should resist penetration; their deficiency of weight, renders their momentum nugatory. When in combination, *they* are not perceived, but the *bodies* with which they combine; and it is only by the changes they produce in such bodies, or their effects upon our nerves, that they can be detected.

"I think it indeed highly probable, that every species of matter, both solid and liquid, follows an increasing rate in its enlargement by caloric. Each portion that enters into a body must weaken the antagonist force, cohesion, and must therefore render more efficacious the operation of the next portion that is introduced. Let 1000 represent the cohesive attraction at the commencement, then, after receiving one increment of caloric, it will become 1000— 1 = 999. Since the next unit of that divellent agent will have to combat only this diminished cohesive force, it will produce an effect greater than the first, in the proportion of 1000 to 999, and so on in continued progression. That the increasing ratio is, however, greatly less than Mr. Dalton maintains, may, I think, be clearly demonstrated." P. 34.

The chief object of the second chapter of that memoir, is the measure of temperature. The experiments on which the reasoning of that part is founded, were made in the years 1812 and 1813, in the presence of many philosophical friends and pupils. By means of two admirable micrometer microscopes of Mr. Troughton's construction, attached to a peculiar pyrometer, I found, that between the temperatures of melting ice, and the 540th degree Fahr., the apparent elongations of rods of pure copper and iron corresponded *pari passu* with the indications of two mercurial thermometers of singular nicety, made by Mr. Crighton of Glasgow, one of which cost three guineas, and the other two, and they were compared with a very fine one of Mr Troughton's. I consider the above results, and others contained in that same paper, as decisive against Mr. Dalton's hypothetical graduation of thermometers. They were obtained and detailed in public lectures many years before the elaborate researches of Messrs. Petit and Dulong on the same subject appeared; and indeed the paper itself passed through Dr. Thomson's hands, to London, many months before the excellent dissertation of the French philosophers was published. Their memoir gained a well-merited prize, voted by the Academy of Sciences, on the 16th of March 1818. My paper was submitted the preceding summer, in its finished state, to three professors of the University of Glasgow, as well as to Dr. Brewster and Dr. Murray.

The researches of MM. Dulong and Petit are contained in the 7th volume of the Annales de Chimie et Physique. They commence with some historical details, in which they observe, "that Mr. Dalton, considering this question from a point of view much more elevated, has endeavoured to establish general laws applicable to the measurement of all temperatures. These laws, it must be acknowledged, form an imposing whole by their regularity and simplicity. Unfortunately, this skilful philosopher proceeded with too much rapidity to generalize his very ingenious notions, but which depended on uncertain *data*. The consequence is, that there is scarcely one of his assertions but what is contradicted by the result of the researches, which we are now going to make known." M. Gay-Lussac had previously shown, that between the limits of freezing and boiling water, a mercurial and air thermometer did not present any sensible discordance. The following table of MM. Dulong and Petit gives the results from nearly the freezing to the boiling point of mercury.

TABLE of Comparison of the Mercurial and Air Thermometer.

Temperature indicated by the mercurial.		Corresponding vols. of the same mass of air.	Temperature indicated by an air thermometer, corrected for the dilatation of glass.	
Centigr.	Fahr.		Centigr.	Fahr.
—36°	—32.8°	0.8650	—36.00°	—32 8°
0	+32.	1.0000	0.00	+32.0
100	212	1.3750	100.00	212.0
150	302	1.5576	148.70	299.66
200	392	1.7389	197.05	386.69
250	482	1.9189	245.05	475 09
300	572	2. 76	292.70	558.86
Boiling, 360	680	2.3125	350.00	662.00

The well known uniformity in the principal physical properties of all the gases, and particularly the perfect identity in the laws of their dilatation, render it very probable, that in this class of bodies the disturbing causes, to which I have adverted in my paper, have not the same influence as in solids and liquids; and that consequently the changes in volume produced by the action of heat upon air and gases, are more immediately dependent upon the force which produces them. It is therefore very probable, that the greatest number of the phenomena relating to heat will present themselves under a more simple form, if we measure the temperatures by an air thermometer.

I coincide with these remarks of the French chemists, and think they were justified by such considerations to employ the scale of an air thermometer in their subsequent researches, which form the second part of their memoir on the laws of the communication of heat.

The boiling point of mercury, according to M M. Dulong and Petit, measured by a true thermometer, is 662° of Fahr. degrees. Now by Mr. Crighton's thermometer the boiling point is 656°, a difference of only 6° in that prodigious range. Hence we see, as I pointed out in my paper, that there is a compensation produced between the unequable expansions of mercury and glass, and the lessening mass of mercury remaining in the bulb as the temperature rises whereby his thermometer becomes a true measurer of the increments of sensible caloric. From all the experiments which have been made with care, we are safe in assuming the apparent expansion of mercury in glass to be 1-63d part of its volume on an average for every 180° Fahr. between 32° and 662°, or through an interval of 7 times 90 degrees. Hence the apparent expansion in glass for the whole is, $\frac{7}{126} = \frac{1}{18} = \frac{630}{18} = 35°$ Fahr.

Were the whole body of the thermometer, stem and bulb, immersed in boiling mercury, it would therefore indicate 35° more than it does when the bulb alone is immersed, or it would mark nearly 691° by Crighton. But the abstraction made of these 35°, in consequence of the bulb alone being immersed in the heated liquids, brings back the common mercurial scale, when well executed, near to the absolute and just scale of an air thermometer, corrected for the expansions of the containing glass.

Dr. Thomson in his Annals for March, 1819, has, in his account of my paper, hazarded some remarks on this subject, which it will be necessary merely to quote in order to see their futility: "From Mr. Crighton's mode of graduating thermometers," says he, "it is obvious that in the higher parts of the scale the degrees are below the truth. Thus mercury boils, as determined by his thermometers, at 556°, the real boiling point, as determined by Dulong and Petit, is 580°. It is probable that Dr. Ure also employed a thermometer, made by Crighton. But it is unlikely that it should be better than mine, as Mr. Crighton was at great pains to make mine as correct as possible, and I paid him a high price for it." Making due allowance for the oblique censure of this insinuation, as well as for the typographical error of 580° instead of 680°, it is obvious that Dr. Thomson has misunderstood the merits of the discussion. The *real* temperature of boiling mercury by Dulong and Petit is 662° F.; the *apparent* temperature, measured by mercury in glass, *both* heated to the boiling point of the former, is 680°. But the latter is a false indication, and Mr. Crighton's compensated number 656° is very near the truth. We may therefore consider a well made mercurial thermometer as a sufficiently just measurer of temperature. For its construction and graduation, see THERMOMETER.

2. Of the distribution of heat.

This head naturally divides into two parts; first, the modes of distribution, or the laws of cooling, and the communication of heat among aeriform, liquid, and solid substances, and, secondly, the specific heats of different bodies at the same and at different temperatures.

The first views relative to the laws of the communication of heat are to be found in the *opuscula* of Newton. This great philosopher assumes *a priori*, that a heated body exposed to a constant cooling cause, such as the uniform action of a current of air, ought to lose at each instant a quantity of heat proportional to the excess of its temperature above that of the ambient air; and that consequently its losses of heat in equal and successive portions of time ought to form a decreasing geometrical progression. Though Martin, in his Essays on Heat, pointed out long ago the inaccuracy of the preceding law, which indeed could not fail to strike any person, as it struck me forcibly the moment that I watched the progressive cooling of a sphere of oil which had been heated to the 500th degree, yet the proposition has been passed from one systematist to another without contradiction.

Erxleben proved, by very accurate observations, that the deviation of the supposed law increases more and more as we consider greater differences of temperatures; and concludes that we should fall into very great errors if we extended the law much beyond the temperature at which it has been verified. Yet Mr. Leslie since, in his ingenious researches on heat, has made this law the basis of several determinations, which from that very cause are inaccurate, as has been proved by Dulong and Petit. At length these gentlemen have investigated the true law in a masterly manner.

When a body cools *in vacuo*, its heat is entirely dissipated by radiation. When it is placed in air, or in any other fluid, its cooling becomes more rapid, the heat carried off by the fluid being in that case added to that which is dissipated by radiation. It is natural therefore to distinguish these two effects; and as they are subject in all probability to different laws, they ought to be separately studied.

MM. Dulong and Petit employed in this research mercurial thermometers, whose bulbs were from 0.8 of an inch to 2.6; the latter containing about three lbs. of mercury. They found by preliminary trials, that the *ratio* of cooling was not affected by the size of the bulb, and that it held also in comparisons of mercury, with water, with absolute alcohol, and with sulphuric acid, through a range of temperature, from 60 to 30 of the centigrade scale; so that the ratio of the velocity of cooling between 60 and 50, and 40 and 30, was sensibly the same. On cooling water in tin plate, and in a glass sphere, they found the law of cooling to be more rapid in the former, at temperatures under the boiling point; but by a very remarkable casualty, the contrary effect takes place in bodies heated to high temperatures, when the law of cooling in tin plate becomes least rapid. Hence, generally, that which cools by a most rapid law at the lower part of the scale, becomes the least rapid at high temperatures.

"Mr. Leslie obtained such inaccurate results respecting this question, because he did not make experiments on the cooling of bodies raised to high temperatures," say MM. Dulong and Petit, who terminate their preliminary researches by experiments on the cooling of water in three tin-plate vessels of the same capacity, the first of which was a sphere, the second and third cylinders; from which we learn that the law of cooling is not affected by the difference of shape.

The researches on cooling in a vacuum were made with an exhausted balloon; and a compensation was calculated for the minute quantity of residuary gas. The following series was obtained when the balloon was surrounded with ice. The degrees are centigrade.

Excess of the therm. above the balloon.	Corresponding velocities of cooling.
240°	10.69
220	8.81
200	7.40
180	6.10
160	4.89
140	3.88
120	3.02
100	2.30
80	1.74

The first column contains the excesses of temperature above the walls of the balloon; that is to say, the temperatures themselves, since the balloon was at 0°. The second column contains the corresponding velocities of cooling, calculated and corrected. These velocities are the numbers of degrees that the thermometer would sink in a minute. The first series shows clearly the inaccuracy of the geometrical law of Richmann; for according to that law, the velocity of cooling at 200° should be double of that at 100°; whereas we find it as 7.4 to 2.3, or more than triple; and in like manner, when we compare the loss of heat at 240° and at 80°, we find the first about 6 times greater than the last; while, according to the law of Richmann, it ought to be merely triple. From the above and some analogous experiments, the following law has been deduced: *When a body cools* in vacuo *surrounded by a medium whose temperature is constant, the velocity of cooling for excess of temperature in arithmetical progression, increases as the terms of a geometrical progression, diminished by a certain quantity*. Or, expressed in algebraic language, the following equation contains the law of cooling in *vacuo*: $V = m.a^{\theta}(a^{t}—1)$.

θ is the temperature of the substance surrounding the vacuum; and t that of the heated body above the former. The ratio a of this progression is easily found for the thermometer, whose cooling is recorded above; for when θ augments by 20°, t remaining the same, the velocity of cooling is then multiplied by 1.165; which number is the mean of all the ratios experimentally determined. We have then $a = \sqrt[20]{1.165} = 1.0077$.

It only remains, in order to verify the accuracy of this law, to compare it with the different series contained in the table inserted above. In that case, in which the surrounding medium was 0°, it is necessary to make $m = 2.037$, for $m = \frac{n}{\log. a}$, and n is an intermediate number; we have then $V = 2.037\,(a^{t} — 1)$.

Excesses of temp. or values of t.	*Values of V observed.*	*Values of V calculated.*
240°	10.69	10.68
220	8.81	8.89
200	7.40	7.34
180	6.10	6.03
160	4.89	4.87
140	3.88	3.89
120	3.02	3.05
100	2.30	2.33
80	1.74	1.72

The laws of cooling *in vacuo* being known, nothing is more simple than to separate from the total cooling of a body surrounded with air, or with any other gas, the portion of the effect due to the contact of the fluid. For this, it is obviously sufficient to subtract from the real velocities of cooling, those velocities which would take place if the body *cæteris paribus* were placed *in va-*

cuo. This subtraction may be easily accomplished now that we have a formula, which represents this velocity with great precision, and for all possible cases.

From numerous experimental comparisons the following law was deduced: *The velocity of cooling of a body, owing to the sole contact of a gas, depends for the same excess of temperature, on the density and temperature of the fluid; but this dependence is such, that the velocity of cooling remains the same, if the density and the temperature of the gas change in such a way that the elasticity remains constant.*

If we call P the cooling power of air under the pressure p, this power will become P (1.366) under a pressure $2p$; P $(1.366)^2$ under a pressure $4p$; and under a pressure $p\,2^n$, it will be P $(1.366)^n$. Hence $\frac{P'}{P} = \left(\frac{p'}{p}\right)^{0.45}$. We shall find in the same way for hydrogen, $\frac{P'}{P} = \left(\frac{p'}{p}\right)^{0.38}$.

For carbonic acid, the exponent will be 0.517, and for olefiant gas 0.501, while for air as we see it is 0.45. These last three numbers differing little from 0.5 or ½, we may say that in the aeriform bodies to which they belong, the cooling power is nearly as the square root of the elasticity. "If we compare the law which we have thus announced," say MM. Dulong and Petit, "with the approximations of Leslie and Dalton, we shall be able to judge of the errors into which they have been led by the inaccurate suppositions which serve as the basis of all their calculations, and by the little precision attainable by the methods which they have followed." But for these discussions, we must refer to the memoir itself.

The influence of the nature of the surface of bodies in the distribution of heat, was first accurately examined by Mr. Leslie. This branch of the subject is usually called the radiation of caloric. To measure the amount of this influence with precision, he contrived a peculiar instrument, called a differential thermometer. It consists of a glass tube, bent into the form of the letter U, terminated at each end with a bulb. The bore is about the size of that of large thermometers, and the bulbs have a diameter of 1-3d of an inch and upwards. Before hermetically closing the instrument, a small portion of sulphuric acid, tinged with carmine is introduced. The adjustment of this liquid so as to make it stand at the top of one of the stems, immediately below the bulb, requires dexterity in the operator. To this stem a scale divided into 100 parts is attached, and the instrument is then fixed upright by a little cement on a wooden sole. If the finger, or any body warmer than the ambient air, be applied to one of these bulbs, the air within will be heated, and will of course expand, and issuing in part from the bulb, depress before it the tinged liquor. The amount of this depression observed upon the scale, will denote the difference of temperature of the two balls. But if the instrument be merely carried without touching either ball, from a warmer to a cooler, or from a cooler to a warmer air, or medium of any kind, it will not be affected; because the equality of contraction or expansion in the enclosed air of both bulbs, will maintain the equilibrium of the liquid in the stem. Being thus independent of the fluctuations of the surrounding medium, it is well adapted to measure the calorific emanations of different surfaces, successively converged by a concave reflector, upon one of its bulbs. Dr. Howard has described, in the 16th number of the Journal of Science, a differential thermometer of his contrivance, which he conceives to possess some advantages. Its form is an imitation of Mr. Leslie's; but it contains merely tinged alcohol, or ether, the air being expelled by ebullition previous to the hermetical closure of the instrument. The vapour of ether, or of spirit *in vacuo*, affords, he finds, a test of superior delicacy to air. He makes the two legs of different lengths; since it is in some cases very convenient to have the one bulb standing quite aloof from the other. In Mr. Leslie's, when they are on the same level, their distance asunder varies from 1-3d of an inch to 1 or upwards, according to the size of the instrument. The general length of the legs of the syphon is about 5 or 6 inches.

His reflecting mirrors, of about 14 inches diameter, consisted of planished tin-plate, hammered into a parabolical form by the guidance of a curvilinear gauge. A hollow tin vessel, 6 inches cube, was the usual source of calorific emanation in his experiments. He coated one of its sides with lampblack, another with paper, a third with glass, and a fourth was left bare. Having then filled it with hot water, and set it in the line of the axis, and 4 or 6 feet in front of one of the mirrors, in whose focus the bulb of a differential thermometer stood, he noted the depression of the coloured liquid produced on presenting the different sides of the cube towards the mirror in succession. The following table gives a general view of the results, with these, and other coatings:

Lampblack, - -	100
Water by estimate, -	100 +
Writing paper, - -	98
Rosin, - - -	96

Sealing wax,	95
Crown glass,	90
China ink,	88
Ice,	85
Red lead,	80
Plumbago,	75
Isinglass,	75
Tarnished lead,	45
Mercury,	20 +
Clean lead,	19
Iron polished,	15
Tin plate,	12
Gold, Silver, Copper,	12

Similar results were obtained by Leslie and Rumford in a simpler form. Vessels of similar shapes and capacities, but of different materials, were filled with hot liquids, and their rates of refrigeration noted. A blackened tin globe cooled a certain number of degrees in 81 minutes; while a bright one took nearly double the time, or 156 minutes; a naked brass cylinder in 55 minutes cooled ten degrees, while its fellow cased in linen, was 36½ minutes in cooling the same quantity. If rapid motions be excited in the air, the difference of cooling between bright and dark metallic surfaces becomes less manifest. Mr. Leslie estimates the diminution of effect from a radiating surface to be directly as its distance, so that double the distance gives one-half, and treble one-third of the primitive heating impression on thermometers and other bodies. Some of his experiments do not seem in accordance with this simple law. One would have expected certainly, that, like light, electricity, and other qualities emanating from a centre, its diminution of intensity would have been as the square of the distance; and particularly as Mr. Leslie found the usual analogy of the sine of inclination to hold, in presenting the faces of the cube to the plane of the mirror under different angles of obliquity.

Some practical lessons flow from the preceding results. Since bright metals project heat most feebly, vessels which are intended to retain their heat, as tea and coffee-pots, should be made of bright and polished metals. Steam-pipes intended to convey heat to a distant apartment, should be likewise bright in their course, but darkened when they reach their destination.

By coating the bulb of his thermometer with different substances, Mr. Leslie ingeniously discovered the power of different surfaces to absorb heat; and he found this to follow the same order as the radiating or projecting quality. The same film of silver leaf which obstructs the egress of heat from a body to those surrounding it, prevents it from receiving their calorific emanations in return. On this principle we can understand how a metallic mirror placed before a fire, should scorch substances in its focus, while itself remains cold; and, on the other hand, how a mirror of darkened or even of silvered glass, should become intolerably hot to the touch, while it throws little heat before it. From this absorbent faculty it comes, that a thin pane of glass intercepts almost the whole heat of a blazing fire, while the light is scarcely diminished across it. By degrees indeed, itself becoming heated, constitutes a new focus of emanation, but still the energy of the fire is greatly interrupted. Hence also we see why the thinnest sheet of bright tin-foil is a perfect fire-screen; so impervious indeed to heat, that with a masque coated with it, our face may encounter without inconvenience, the blaze of a glass-house furnace.

Since absorption of heat goes hand in hand with radiation in the above table, we perceive that the inverse of absorption, that is reflection, must be possessed in inverse powers by the different substances composing the list. Thus bright metals reflect most heat, and so on upwards in succession.

Mr. Leslie is anxious to prove that elastic fluids, by their pulsatory undulations, are the *media* of the projection or radiation of heat: and that therefore liquids, as well as a perfect vacuum, should obstruct the operation of this faculty. The laws of the cooling of bodies *in vacuo*, experimentally established by MM. Dulong and Petit, are fatal to Mr. Leslie's hypothesis, which indeed was not tenable against the numerous objections which had previously assailed it. The following beautiful experiment of Sir H. Davy seems alone to settle the question. He had an apparatus made, by which platina wire could be heated in any elastic medium or *in vacuo;* and by which the effects of radiation could be distinctly exhibited by two mirrors, the heat being excited by a voltaic battery. In several experiments in which the same powers were employed to produce the ignition, it was found that the temperature of a thermometer rose nearly three times as much in the focus of radiation, when the air in the receiver was exhausted to $\frac{1}{120}$, as when it was in its natural state of condensation. The cooling power, by contact of the rarefied air, was much less than that of the air in its common state, for the glow of the platina was more intense in the first case than in the last; and this circumstance perhaps renders the experiment not altogether decisive, but the results seem favourable to the idea, that the terrestrial radiation of heat is not dependent upon any motions or affections of the atmosphere. The plane of the two mirrors was placed parallel to the horizon, the ignited body being in the focus of the upper, and the thermometer in that of the under mirror. It is evident that a diminished density of the elastic medium, amounting to $\frac{1}{120}$, should, on Mr. Leslie's views, have occasioned a greatly diminished temperature in the inferior focus, and not a threefold increase, as happened; making every allowance for the diminished intensity of glow resulting from the cooling power of atmospheric air. The experiments with screens of glass, paper, &c. which Mr. Leslie adduced in support of his undulatory hypothesis, have been since confronted with the experiments on screens of Dr. Delaroche, who, by varying them, obtained results incompatible with Mr. Leslie's views, and favourable to those on the intimate connexion between light and heat, with which our account of heat was prefaced. He shows that invisible radiant heat, in some circumstances, passes directly through glass, in a quantity so much greater relative to the whole radiation, as the temperature of the source of heat is more elevated. The following table shows the ratio between the rays passing through clear glass, and the rays acting on the thermometer, when no screen was interposed, at successive temperatures.

Temperature of the hot body in the focus.	*Rays transmitted through the glass screen.*	*Total Rays.*
357°	10°	263°
655	10	139
800	10	75
1760	10	34
Argand's lamp without its chimney,	10	29
Do. with glass chimney,	10	18

He next shows that the calorific rays which have already passed through a screen of glass, experience, in passing through a second glass screen of a similar nature, a much smaller diminution of their intensity than they did in passing through the first screen; and that the rays emitted by a hot body differ from each other in their faculty to pass through glass; that a thick glass, though as much as, or more permeable to light than a thin glass of worse quality, allows a much smaller quantity of radiant heat to pass, the difference being so much the less, the higher the temperature of the radiating source. This curious fact, that radiating heat becomes more and more capable of penetrating glass, as the temperature increases, till at a certain temperature the rays become luminous, leads to the notion that heat is nothing else than a modification of light, or that the two substances are capable of passing into each other. Dr. Delaroche's last proposition is, that the quantity of heat which a hot body yields in a given time by radiation to a cold body situated at a distance, increases *cæteris paribus*, in a greater ratio than the excess of temperature of the first body above the second. This proposition, which Dr. Thomson declared in his Annals, vol. ii. p. 102. to be "somewhat puzzling," is in philosophical accordance with the laws of Dulong and Petit.

For some additional facts on radiation, see Light, to which subject indeed, the whole discussion probably belongs.

Even ice, which appears so cold to the organs of touch, would become a focus of heat if transported into a chamber where the temperature of the air was at 0° F.; and a mass of melting ice placed before the mirror, would affect the bulb of the thermometer, just as the cube of heated water did. A mixture of snow and salt at 0°. would in like manner become a warm body when carried into an atmosphere at —40°. In all this, as well as in our sensations, we see nothing absolute, nothing but mere differences. We are thus led to consider all bodies as projecting heat at every temperature, but with unequal intensities, according to their nature, their surfaces, and their temperature. The constancy or steadiness of the temperature of a body, will consist in the equality of the quantities of radiating caloric which it emits and receives in an equal time, and the equality of temperature between several bodies which influence one another by their mutual radiation, will consist in the perfect compensation of the momentary interchanges effected among one and all. Such is the ingenious principle of a moveable equilibrium, proposed by Professor Prevost, a principle whose application, directed with discretion, and combined with the properties peculiar to different surfaces, explains all the phenomena which we observe in the distribution of radiating caloric. Thus, when we put a ball of snow in the focus of one concave mirror, and a thermometer in that of an opposite mirror placed at some distance, we perceive the temperature instantly to fall, as if there were a real radiation of frigorific particles, according to the ancient notion. The true explanation is derived from the abstraction of that return of heat which the thermoscope mirror had previously derived from the one now influenced by the snow, and now participating in its inferior radiating tension. Thus, also a black body placed in the focus of one mirror, would diminish the light in the focus of the other; and, as Sir H. Davy happily remarks, the eye is, to the rays producing light, *a measure*, similar to that which the thermometer is to rays producing heat.

This interchange of heat is finely exemplified in the relation which subsists between any portion of the sky and the temperature of the subjacent surface of the earth. In the year 1788 Mr. Six of Canterbury mentioned, in a paper transmitted to the Royal Society, that on clear and dewy nights he always found the mercury lower in a thermometer laid upon the ground, in a meadow in his neighbourhood, than it was in a similar thermometer suspended in the air 6 feet above the former; and that upon one night the difference amounted to 5° of Fahrenheit's scale. And Dr. Wells, in autumn 1811, on laying a thermometer upon grass wet with dew, and suspending a second in the air 2 feet above the surface, found in an hour afterwards, that the former stood 8° lower than the latter. He at first regarded this coldness of the surface to be the *effect* of the evaporation of the moisture, but subsequent observations and experiments convinced him, that the cold was not the effect, but the *cause* of deposition of dew. Under a cloudless sky, the earth projects its heat without return, into empty space; but a canopy of cloud is a concave mirror, which restores the equilibrium by counter-radiation. See Dew.

On this principle Professor Leslie has constructed a pretty instrument, which he calls Æthrioscope, whose function it is to denote the clearness and coolness of the sky. It consists of a polished metallic cup, of an oblong spheroidal shape; very like a silver porter-cup, standing upright, with the bulb of a differential thermometer placed in its axis, and the stem lying parallel to the stalk of the cup. The other ball is gilt, and turned outwards and upwards, so as to rest against the side of the vessel. The best form of the cup is an ellipsoid, whose eccentricity is equal to half the transverse axis, and the focus consequently placed at the third part of the whole height of the cavity; while the diameter of the thermoscope ball should be nearly the third part of the orifice of the cup. A lid of the same thin metal unpolished, is fitted to the mouth of the cup, and removed only when an observation is to be made. The scale attached to the stem of the thermoscope, may extend to 60 or 70 millesimal degrees above the zero, and about 15 degrees below it.

This instrument exposed to the open air in clear weather, will at all times, both during the day and the night, "indicate an impression of cold shot downward from the higher regions," in the figurative language of the inventor. Yet the effect varies exceedingly. It is greatest while the sky has the pure azure hue; it diminishes fast as the atmosphere becomes loaded with spreading clouds; and it is almost extinguished when low fogs settle on the surface. The liquid in the stem falls and rises with every passing cloud. Dr. Howard's modification of the thermoscope would answer well here.

The diffusion of heat among the particles of fluids *themselves*, depends upon their specific gravity and specific heat conjunctly, and therefore must vary for each particular substance. The mobility of the particles in a fluid, and their reciprocal independence on one another, permit them to change their places whenever they are expanded or contracted by alternations of temperature; and hence the immediate and inevitable effect of communicating heat to the under stratum of a fluid mass, or of abstracting it from the upper stratum, is to determine a series of intestine movements. The colder particles, by their superior density, descend in a perpetual current, and force upwards those rarefied by the heat. When however the upper stratum *primarily* acquires an elevated temperature, it seems to have little power of imparting heat to the subjacent strata of fluid particles. Water may be kept long in ebullition at the surface of a vessel, while the bottom remains ice cold, provided we take measures to prevent the heat passing downwards through the sides of the vessel itself. Count Rumford became so strongly persuaded of the impossibility of communicating heat downwards through fluid particles, that he regarded them as utterly destitute of the faculty of transmitting that power from one to another, and capable of acquiring heat, only in individual rotation and directly, from a foreign source. The proposition thus absolutely announced is absurd, for we know that by intermixture and many other modes, fluid particles impart heat to each other; and experiments have been instituted, which prove the actual descent of heat through fluids by communication from one stratum to another. But unquestionably this communication is amazingly difficult and slow. We are hence led to conceive, that it is an actual contact of particles, which in the solid condition facilitates the transmission of heat so speedily from point to point through their mass. This contact of certain poles in the molecules, is perfectly consistent with void spaces, in which these molecules may slide over each other in every direction; by which movements or condensations, heat may be excited. The fluid condition *reverts* or *averts* the touching and cohering poles, whence mobility results. This statement may be viewed either as a representation of facts, or an hypothesis to aid conception.

Since the diffusion of heat through a fluid mass is accomplished almost solely by the intestine currents, whatever obstructs these must obstruct the change of temperature. Hence fluids intermingled with porous matter, such as silk, wool, cotton, downs, fur, hair, starch, mucilage, &c. are more slowly cooled than in their pure and limpid state. Hence apple-tarts and pottages retain their heat very long, in comparison of the same bulk of water heated to the same degree, and exposed in similar covered vessels to the cool air. Of the conducting power of gaseous bodies, we have already taken a view. I know of no experiments which have satisfactorily determined in numbers, the relative conducting power of liquids. Mercury for a liquid, possesses a high conducting faculty, due to its density and metallic nature, and small specific heat.

The transmission of heat through solids was made the subject of some pleasing popular experiments by Dr. Ingenhausz. He took a number of metallic rods of the same length and thickness, and having coated one of the ends of them for a few inches with bees wax, he plunged their other ends into a heated liquid. The heat travelled onwards among the matter of each rod, and soon became manifest by the softening of the wax. The following is the order in which the wax melted; and according to that experiment, therefore, the order of conducting power relative to heat.

1. Silver.
2. Gold.
3. Copper, } nearly equal.
4. Tin,
Platinum, } much inferior to the others.
Iron,
Steel,
Lead,

In my repetition of the experiment, I found silver by much the best conductor, next copper, then brass, iron, tin, much the same, then cast iron, next zinc, and last of all, lead. Dense stones follow metals in conducting power, then bricks, pottery, and at a long interval, glass. A rod of this singular body may be held in the fingers for a long time, at a distance of an inch from where it is ignited and fused by the blow-pipe. It is owing to the inferior conducting power of stone, pottery, glass, and cast iron, that the sudden application of heat so readily cracks them. The part acted on by the caloric expands, while the adjacent parts retaining their pristine form and volume, do not accommodate themselves to the change; whence a fissure must necessarily ensue. Woods and bones are better conductors than glass; but the progress of heat in them at elevated temperatures, may be aided by the vaporization of their juices. Charcoal and saw-dust rank very low in conducting power. Hence the former is admirably fitted for arresting the dispersion of heat in metal furnaces. If the sides of these be formed of double plates, with an interval between them of an inch filled with pounded charcoal, an intense heat may exist within, while the outside is scarcely affected. Morveau has rated the conducting power of charcoal to that of fine sand, as 2 to 3, a difference much too small. Spongy organic substances, silk, wool, cotton, &c. are still worse conductors than any of the above substances; and the finer the fibres, the less conducting power they possess. The theory of clothing depends on this principle. The heat generated by the animal powers, is accumulated round the body by the imperfect conductors of which clothing is composed.

To discover the exact law of the distribution of heat in solids, let us take a prismatic bar of iron, three feet long, and with a drill form three cavities in one of its sides, at 10, 20, and 30 inches from its end, each cavity capable of receiving a little mercury, and the small bulb of a delicate thermometer. Cut a hole fitting exactly the prismic bar, in the middle of a sheet of tin-plate, which is then to be fixed to the bar, to screen it and the thermometer, from the focus of heat. Immerse the extremity of the bar obliquely into oil or mercury heated to any known degree, and place the thermometers in their cavities surrounded with a little mercury. Or the bar may be kept horizontal, if an inch or two at its end be incurvated, at right angles to its length. Call the thermometers A, B, C. Were there no dissipation of the heat, each thermometer would continue to mount till it attained the temperature of the source of heat. But in actual experiments, projection and aerial currents modify that result, making the thermometers rise more slowly, and preventing them from ever reaching the temperature of the end of the bar. Their state becomes indeed stationary whenever the excess of temperature, each instant communicated by the preceding section of the bar, merely compensates what they lose by the contact of the succeeding section of the bar, and the other outlets of heat. The three thermometers now indicate three steady temperatures, but in diminishing progression. In forming an equation from the experimental results, M. Laplace has shown, that the difficulties of the calculation can be removed only by admitting, that a determinate point is influenced not only by those points which touch it, but by others at a small distance before and behind it. Then the laws of homogeneity, to which differentials are subject, are re-established, and all the rules of the differential calculus are observed. Now, in order that the calorific influence may thus extend to a distance in the interior of the bar, there must operate through the very substance of the solid elements a true radiation, analogous to that observed in air, but whose sensible influence is bounded to distances incomparably smaller. This result is in no respect improbable. In fact, Newton has taught us, that all bodies, even the most opaque, become transparent when rendered sufficiently thin; and the most exact researches on radiating caloric, prove that it does not emanate solely from the external surface of bodies, but also from material particles situated within this surface, becoming no doubt insensible at a very slight depth, which probably varies in the same body, with its temperature.

M. Biot, M. Fourier, and M. Poisson, three of the most eminent mathematicians and philosophers of the age, have distinguished themselves in this abstruse investigation. The following is the formula of M. Biot, when one end of the bar is maintained at a constant temperature, and the other is so remote as to make the influence of the source insensible. Let y represent, in degrees of the thermometer, the temperature of the air by which the bar is surrounded; let the temperature of the focus be $y + \mathrm{Y}$; then the integral becomes,

$$\log. y = \log. \mathrm{Y} - \frac{x}{\mathrm{M}} \sqrt{\frac{b}{a}}.$$

x is the distance from the hot end of the bar; a and b are two coefficients, supposed constant for the whole length of the bar, which serve to accommodate the formula to every possible case, and which must be assigned in such case, agreeably to two observations. M is the modulus of the ordinary logarithmic tables, or the number 2.302585. M. Biot presents several tables of observations, in which sometimes 8, and sometimes 14 thermometers were applied all at once to successive points of the bar; and then he computes by the above formula, what ought to be the temperature of these successive points, having given the temperature of the source; and *vice versa*, what should be the temperature of the source from the indications of the thermometers. A perfect accordance is shown to exist between fact and theory. Whence we may regard the view opened up by the latter, as a true representation of the condition of the bar. With regard to the application of this theorem, to discover for example, the temperature of a furnace, by thrusting the end of a thermoscopic iron bar into it, we must regret its insufficiency. M. Biot himself after showing its exact coincidence at all temperatures, up to that of melting lead, declares that it ought not to apply at high heats. But I see no difficulty in making a very useful instrument of this kind, by *experiment*, to give very valuable pyrometrical indications. The end of the bar which is to be exposed to the heat, being coated with fire-clay, or sheathed with platinum, should be inserted a few inches into the flame, and drops of oil being put into three successive cavities of the bar, we should measure the temperatures of the oil, when they have become stationary and note the time elapsed, to produce this effect. A pyroscope of this kind could not fail to give useful information to the practical chemist, as well as to the manufacturers of glass, pottery, steel, &c.

2. *Of specific heat.*—If we take equal weights, or equal bulks, of a series of substances; for example, a pound or a pint of water, oil, alcohol, mercury, and having heated each separately, in a thin vessel, to the same temperature, say to 80° or 100° Fahr. from an atmospherical temperature of 60°, then in the subsequent cooling of these four bodies to their former state, they will communicate to surrounding media very different quantities of heat. And conversely, the quantity of heat requisite to raise the temperature of equal masses of different bodies, an equal number of thermometric degrees, is different, but specific for each body. There is another point of view in which specific heats of bodies may be considered relative to their change of form, from gaseous to liquid, and from liquid to solid. Thus the steam of water, at 212°, in becoming a liquid, does not change its thermometric temperature 212°, yet it communicates, by this change, a vast quantity of heat to surrounding bodies; and, in like manner, liquid water at 32°, in becoming the solid called ice, does not change its temperature as measured by a thermometer, yet it imparts much heat to surrounding matter. We therefore divide the study of specific heats into two branches: 1. The specific heats of bodies while they retain the same state; and 2. The specific heats, connected with, or developed by, change of state. The first has been commonly called the capacities of bodies for caloric; the second, the latent heat of bodies. The latter we shall consider after *change of state.*

1. Of the specific heats of bodies, while they experience no change of state.

Three distinct experimental modes have been employed to determine the specific heats of bodies; in the whole of which modes, that of water has been adopted for the standard of comparison or unity. 1. In the *first* mode, a given weight or bulk of the body to be examined, being heated to a certain point, is suddenly mixed with a given weight or bulk of another body, at a different temperature; and the resulting temperature of the mixture shows the relation between their specific heats. Hence, if the second body be water, or any other substance whose relation to water is ascertained, the relative heat of the first to that of water will be known. It is an essential precaution in using this mode, to avoid all such chemical action as happens in mixing water with alcohol or acids. Let us take oil for an example. If a pound of it, at 90° Fahr. be mixed with a pound of water at 60°, the resulting temperature will not be the mean 75°, but only 70°. And conversely, if we mix a pound of water heated to 90°, with a pound of oil at 60°, the temperature of the mixture will be 80°. We see here, that the water in the first case acquired 10°, while the oil lost 20°; and in the second case, that the water lost 10° while the oil gained 20°. Hence we say, that the specific heat of water is double to that of oil; or that the same quantity or intensity of heat which will change the temperature of oil 20°, will change that of water only 10°; and therefore if the specific heat, or capacity for heat, of water be called 1.000, that of oil will be 0.500. When the experiment has been, from particular circumstances, made with unequal weights, the obvious arithmetical reduction, for the difference, must be made. This is the original method of Black, Irvine, and Crawford.

The *second* mode is in some respects a modification of the first. The heated mass of the matter to be investigated, is so surrounded by a large quantity of the standard substance at an inferior temperature, that the whole heat evolved by the first, in cooling, is received by the second. We may refer to this mode, 1*st*, Wilcke's practice of suspending a lump of heated metal in the centre of a mass of cold water contained in a tin vessel: 2*d*, The plan of Lavoisier and Laplace, in which a heated mass of matter was placed by means of their elegant CALORIMETER, in the centre of a shell of ice; and the specific heat was inferred from the quantity of ice that was liquefied: And 3*d*, The method of Berard and Delaroche, in which gaseous matter, heated to a known temperature, was made to traverse, slowly and uniformly, the convolutions of a spiral pipe, fixed in a cylinder of cool water, till this water rose to a stationary temperature; when "reckoning from this point, the excess of the temperature of the cylinder, above that of the ambient air, becomes proportional to the quantity of heat given out by the current of gas that passed through the cylinder." Each gas was definitely heated, by being passed through a straight narrow tube, placed in the axis of a large tube, filled with the steam of boiling water. The specific heats were then compared to water by two methods. The first consists in subjecting the cylinder, which they call the *calorimeter*, to the action of a current of water perfectly regular, and so slow, that it will hardly produce a greater effect than the current of the different gases. The second method consists in determining, by calculation, the real quantity of heat which the calorimeter, come to its stationary temperature, can lose in a given time; for since, after it reaches this point, it does not become hotter, though the source of heat continues to be applied to it, it is evident that it loses as much heat as it receives. MM. Berard and Delaroche employed these two methods in succession. From the singular ingenuity of their apparatus, and precision of their observations, we may regard their determinations as deserving a degree of confidence to which the previous results, on the specific heat of the gases, are not at all entitled. They have completely overturned the hypothetical structures of Black, Lavoisier, and Crawford, on the heat developed in combustion and respiration, while they give great countenance to the profound views of Sir H. Davy. See COMBUSTION.

The *third* method of determining the specific heats of bodies, is by raising a given mass to a certain temperature, suspending it in a uniform cool medium, till it descends through a certain number of thermometric degrees, and carefully noting by a watch the time elapsed. It is evident, that if the bodies be invested with the same coating, for instance, glass or burnished metals; if they be suspended in the same medium, with the same excess of temperature, and if their interior constitution relative to the conduction of heat be also the same, then their specific heats will be directly as the times of cooling. I have tried this method, and find that it readily gives, in common cases, good approximations. Some of my results were published in the Annals of Phil. for October 1817, on water, sulphuric acid, spermaceti oil, and oil of turpentine. "A thin glass globe, capable of holding 1800 grains of water, was successively filled with this liquid, and with the others; and being in each case heated to the same degree, was suspended, with a delicate thermometer immersed in it, in a large room of uniform temperature. The comparative times of cooling, through an equal range of the thermometric scale, were carefully noted by a watch in each case." The difference of mobility in the liquid particles may be regarded as very trifling, at temperatures from 100° to 200°. At inferior temperatures, under 80° for example, oil of vitriol, as well as spermaceti oil, becoming viscid, would introduce erroneous results.

This mode has been lately practised with the utmost scientific refinement by MM. Dulong and Petit. Their experiments were made on metals reduced to fine filings, strongly pressed into a cylindrical vessel of silver, very thin, very small, and the axis of which was occupied by the reservoir of the thermometer. This cylinder, containing about 460 grains of the substance, heated about 12° F. above the ambient medium, was suspended in the centre of a vessel blackened interiorly, surrounded with melting ice, and exhausted of air, to prolong the period of refrigeration, which lasted generally 15 minutes. Their results have disclosed a beautiful and unforeseen relation, between the specific heats and primitive combining ratios or atoms of the metals; namely, *that the atoms of all simple bodies have exactly the same capacity for heat.* Hence the specific heat of a simple substance, multiplied into the weight of its atom or prime equivalent, ought to give always the same product.

The law of specific heats being thus established for elementary bodies, it became very important to examine, under the same point of view, the specific heats of compound bodies. The process applying indifferently to all substances, whatever be their conductibility or state of aggregation, they had it in their power to subject to experiment, a great many bodies whose proportions may be considered as fixed; but when they endeavoured to mount from these determinations to that of the specific heat of each compound atom, by a method analogous to that employed for the simple bodies, they found themselves stopped by the number of equally probable suppositions among which they had to choose. "If the method," say they, "of fixing the weights of the atoms of simple bodies has not yet been subjected to any certain rule, that of the atoms of compound bodies has been, *a fortiori*, deduced from suppositions purely arbitrary." They satisfy themselves by saying, in the mean time, that, abstracting every particular supposition, the observations which they have hitherto made tend to establish this remarkable law, that there always exists a very simple ratio between the capacity for heat of the compound atoms, and that of the elementary atoms.

We shall insert here tabular views of the specific heats determined by the recent researches of these French chemists, reserving, for the end of the volume, the usual more extended, but less accurate tables of specific heat. MM. Petit and Dulong justly remark, that "the attempts hitherto made to discover some laws in the specific heats of bodies have been entirely unsuccessful. We shall not be surprised at this, if we attend to the great inaccuracy of some of the measurements; for if we except those of Lavoisier and Laplace (unfortunately very few), and those by Delaroche and Berard for elastic fluids, we are forced to admit, that the greatest part of the others are extremely inaccurate, as our own experiments have informed us, and as might indeed be concluded from the great discordance in the results obtained for the same bodies by different experimenters." From this censure, we must except the recent results of MM. Clement and Desormes on gases, which I believe may be regarded as entitled to equal confidence with those of Berard and Delaroche.

TABLE I.—*Of the Specific Heats of Gases, by* MM. BERARD *and* DELAROCHE.

	Equal volumes.	*Equal weights.*	*Sp. Gravity.*
Air,	1.0000	1.0000	1.0000
Hydrogen,	0.9033	12.3401	0.0732
Carbonic Acid,	1.2583	0.8280	1.5196
Oxygen,	0.9765	0.8848	1.1036
Azote,	1.0000	1.0318	0.9691
Oxide of Azote,	1.3503	0.8878	1.5209
Olefiant gas,	1.5530	1.5763	0.9885
Carbonic Oxide,	1.0340	1.0805	0.9569

To reduce the above numbers to the standard of water, three different methods were employed; from which the three numbers, 0.2498, 0.2697, and 0.2813 were obtained for atmospheric air. The experimenters have taken 0.2669 as the mean, to which all the above results are referred, as follows:

TABLE II.

Water	1.0000
Air	0.2669
Hydrogen gas	3.2936
Carbonic acid	0.2210
Oxygen	0.2361
Azote	0.2754
Oxide of azote	0.2369
Olefiant gas	0.4207
Carbonic Oxide	0.2884
Aqueous vapour	0.8470

The following are the results given by MM. Clement and Desormes, for equal volumes at temperatures from 0° to 60° centigrade, or 32° to 140° Fahr.

TABLE III.

	Inches Barom.	*Clement & Desormes.*	*Delaroche & Berard.*
Atmospheric air at	39.6	1.215	1.2396
Ditto.	29.84	1.000	1.0000
Ditto.	14.92	0.693	
Ditto.	7.44	0.540	
Ditto.	3.74	0.368	
Do. charged with ether,	29.84	1.000	
Azote,	29.84	1.000	1.0000
Oxygen,	29.84	1.000	0.974
Hydrogen,	29.84	0.664	0.9033
Carbonic acid,	29.84	1.500	1.2583

The relative specific heat of air to water, is by MM. Clement and Desormes 0.250 to 1.000, or exactly one-fourth. The last table which is extracted from the *Jour-*

nal de Physique, gives the specific heat of oxygen by Delaroche and Berard, a little different from their own number, Table I. from the *Annales de Chimie*, vol. 85. The most remarkable result given by M M. Clement and Desormes regards carbonic acid, which being reduced to the standard of weights, gives a specific heat compared to air of about 0.987 to 1.000, while oxygen is only 0.9000. The former tables of Crawford and Dalton give the sp. heat of oxygen 2.65, and of carbonic acid 0.586, compared to air 1.000. And upon these very erroneous numbers, they reared their hypothetical fabric of latent heat, combustion and animal temperature.

We shall refer to the above table in treating of combustion.

We see from the experiments on air, at different densities, that its specific heat diminishes in a much slower rate than its specific gravity. When air is expanded to a quadruple volume, its specific heat becomes 0.540, and when expanded to eight times the volume, its specific heat is 0.368. The densities in the geometrical progression 1. ½ ¼ ⅛ correspond nearly to the specific heats in the arithmetical series 5, 4, 3, 2. Hence also the specific heat of atmospherical air, and of probably all gases, considered in the ratio of its weight or mass, diminishes as the density increases. On the principle of the increase of specific heat, relative to its mass, has been explained the long observed phenomenon of the intense cold which prevails on the tops of mountains, and generally in the upper regions of the atmosphere; and also that of the prodigious evolution of heat, when air is forcibly condensed. According to M. Gay-Lussac, a condensation of volume amounting to four-fifths, is sufficient to ignite tinder. If a syringe of glass be used, a vivid flash of light is seen to accompany the condensation.

TABLE IV.—*Of Specific Heats of some Solids determined by* DULONG *and* PETIT.

	Specific heats, that of water being 100.	*Weight of the atoms, oxygen being* 1.	*Product of these two numbers.*
Bismuth,	0.0288	13.300	0.3830
Lead,	0.0293	12.950	0.3794
Gold,	0.0298	12.430	0.3704
Platinum,	0.0314	11.160	0.3740
Tin,	0.0514	7.350	0.3779
Silver,	0.0557	6.750	0.3759
Zinc,	0.0927	4.030	0.3736
Tellurium,	0.0912	4.030	0.3675
Copper,	0.0949	3.957	0.3755
Nickel,	0.1035	3.690	0.3819
Iron,	0.1100	3.392	0.3731
Cobalt,	0.1498	2.460	0.3685
Sulphur,	0.1880	2.011	0.3780

The above products, which express the capacities of the different atoms, approach so near equality, that the slight differences must be owing to slight errors, either in the measurement of the capacities, or in the chemical analyses, especially if we consider, that in certain cases, these errors derived from these two sources, may be on the same side, and consequently be found multiplied in the result. Each atom of these simple bodies seems, therefore, as was formerly stated, to have the same capacity for heat.

An important question now occurs, whether the relative capacities for heat of different solid and liquid bodies be uniform at different temperatures, or whether it vary with the temperature? This question may be perhaps more clearly expressed thus: Whether a body, in cooling a certain thermometric range at a high temperature, gives out the same quantity of heat that it does in cooling through the same range at a lower temperature? No means seem better adapted for solving this problem, than to measure the refrigeration produced, by the same weights of ice, on uniform weights of water, at different temperatures. Mr. Dalton found in this way, that "176.5° expresses the number of degrees of temperature, such as are found between 200° and 212° of the old or common scale, entering into ice of 32° to convert it into water of 32°; 150° of the same scale, between 122° and 130°, suffice for the same effect; and between 45° and 50°, 128° are adequate to the conversion of the same ice to water. These three resulting numbers, (128, 150, 176.5), are nearly as 5, 6, 7. Hence it follows, that as much heat is necessary to raise water 5° in the lower part of the old scale, as is required to raise it 7° in the higher, and 6° in the middle." *See his New System of Chemical Philos.* vol. i. p. 53.

Mr. Dalton, instead of adopting the obvious conclusion, that the capacity of water for heat is greater at lower than it is at higher temperatures, and that therefore a smaller number of degrees at the former, should melt as much ice as a greater number at the latter, ascribes the deviation denoted by these numbers, 5, 6, and 7, to the gross errors of the ordinary thermometric graduation, which he considers so excessive, as not only to equal, but greatly to overbalance the *really* increased specific heat or capacity of water; which, viewed in itself, he conceives would have exhibited opposite experimental results. That our *old*, and, according to his notions, *obsolete* thermometric scale, has no such prodigious deviation from truth, is, I believe, now fully admitted by chemical philosophers; and therefore the only legitimate inference from these very experiments of Mr. Dalton, is the *decreasing* capacity of water, with the *increase* of its temperature. It deserves to be remarked, that my experiments on the relative times of cooling a globe of glass, successively filled with water, oil of vitriol, common oil, and oil of turpentine, give exactly the same results as Mr. Dalton had derived from mixtures of two ounces of ice with 60 of water, at different temperatures. This concurrence is the more satisfactory, since when my paper on the specific heats of the above bodies, published in the Annals of Philosophy for October 1817, was written, I had no recollection of Mr. Dalton's experiments.

In the Annals of Philosophy for March 1819, Dr. Thomson has made the following remarks in reviewing my paper on heat: "The second topic which Dr. Ure discusses in this paper, is Mr. Dalton's opinion that the common thermometer is an inaccurate measurer of heat, and that mercury and all liquids expand as the square of the temperature, reckoning from the freezing point. It is not necessary to give a particular detail of the facts contained in this part, as Mr. Dalton's opinions on this subject had been already overturned by the experiments of Dulong and Petit. Dr. Ure's notion, that the capacity of bodies for heat diminishes as the temperature increases, is directly contrary to the results of the experiments of Dulong and Petit on the subject. It seems also contrary to analogy in other cases. We know that the capacity of elastic fluids increases as they become rarer, and that the rarest of all the elastic fluids has the greatest capacity. It is reasonable, I think, that this should be the case; for the further the particles of a body are removed from each other, the greater must the quantity of heat be, which shall be capable of producing a given effect on it." From the early part of this passage, readers of the Annals would naturally infer, that I had undertaken a refutation which had been *already* accomplished. But it is consistent with Dr. Thomson's personal knowledge, that my paper on heat was finished and sent off to London many months before the paper of MM. Dulong and Petit was published. Besides, in a question of such vital importance to the whole of physical science, as whether the thermometer be a crude or correct indicator of the increments of temperature, it is surely desirable to have the investigation conducted in *two* original and independent methods. Dr. Thomson has misconceived my views with regard to capacity. I adduce some experimental evidence to show that the capacity of water for heat diminishes as we raise it from the freezing to the boiling point; but I did not so far violate the rules of philosophy, as to make a *general* inference from a *particular* case, a practice, it must be confessed, too common with some chemical writers. So far from asserting the proposition for all bodies, the idea is thrown out, of its being perhaps a property peculiar to water, like that of its expanding by dimiuntion of its heat, after being cooled down to 39°.

The total absence in the gases of cohesive attraction, that power which *governs* the phenomena of solids as to heat, and *modifies* those of liquids, renders the analogy of elastic fluids adduced by Dr. Thomson quite irrelevant. "The above circumstance in water, renders it peculiarly qualified for serving as the magazine and equalizer of the temperature of the globe. Since at our ordinary atmospherical heats, it possesses the greatest capacity for caloric, small variations in its temperature gave it a great modifying power over the circumambient air." See New Experimental Researches on some of the leading doctrines of Caloric, in the Philosophical Transactions for 1818, or in Tilloch's Magazine, vol. 53. I have looked with attention over MM. Dulong and Petit's paper, for the results of their experiments on the subject, which Dr. Thomson pronounces to be directly contrary to mine, but I could find nothing which affects my proposition with regard to water. Their experiments lead them to conclude, that the capacities of the following *metallic* bodies increase with the elevation of their temperature, in the following proportions.

TABLE V.—*Of Capacities for Heat.*

	Mean capacity between 0° and 100°.	*Mean capacity between 0° and 300°.*
Mercury,	0.0330	0.0350
Zinc,	0.0927	0.1015
Antimony,	0.0507	0.0549
Silver,	0.0557	0.0611
Copper,	0.0949	0.1013
Platinum,	0.0355	0.0355
Glass,	0.1770	0.1900

The capacity of iron was determined at the four following intervals:

From 0° to 100°, the capacity is	0.1098
0° to 200	0.1150
0° to 300	0.1218
0° to 350	0.1255

If we estimate the temperatures, as some philosophers have proposed, by the ratios of the quantities of heat which the same body gives out in cooling to a determinate temperature, in order that this calculation be exact, it would be necessary that the body in cooling, for example, from 300° to 0°, should give out three times as much heat as in cooling from 100° to 0°. But it will give out more than three times as much, because the capacities are increasing. We should therefore find too high a temperature. We exhibit in the following table the temperatures that would be deduced by employing the different metals contained in the preceding table. We must suppose that they have been all placed in the same liquid bath at 300°, measured by an air thermometer.

Iron,	332.2°
Mercury,	318.2
Zinc,	328.5
Antimony,	324.8
Silver,	329.3
Copper,	320.0
Platinum,	317.9
Glass,	322.1

Experiments have been instituted, and theorems constructed, for determining the absolute quantity of heat in bodies, and the point of the total privation of that power, or of absolute cold, on the thermometric scale. The general principle on which most of the inquirers have proceeded is due to the ingenuity of Dr. Irvine. Supposing, for example, the capacity of ice to be to that of water as 8 to 10, at the temperature of 32°, we know that in order to liquefy a certain weight of ice, as much heat is required as would heat the same weight of water to 140° Fahr. Hence 140° represent two-tenths or one-fifth of the whole heat of fluid water; and therefore the whole heat would be 5 × 140° = 700° below 32°. It is needless to present any algebraic equations on a principle which is probably erroneous, and which has certainly produced in experiment most discordant results. Mr. Dalton has given a general view of them in his section on the zero of temperature.

If we estimate the capacity of ice to that of water as 9 to 10, then the zero will come out - - - - - 1400°

Gadolin, from the heat evolved 2936°
in mixing sulphuric acid and water 1710
in different proportions, and compa- 1510
ring the capacity of the compound 2637
with those of its components, dedu- 3230
ced the opposite numbers, 1740

Mr. Dalton, from sulphuric acid and water, - - - - - - 6400°
Do. do. do. 4150
Do. do. do. 6000

He thinks these to be no nearer approximations to the truth than Gadolin's.

From the heat evolved in slaking lime, compared to the specific heats of the compound, and its constituents, lime and water, Mr. Dalton gives as the zero, 4260

From nitric acid and lime, Mr. Dalton finds - - - - 11000

From the combustion of hydrogen, 5400

From Lavoisier and Laplace's experiments on slaked lime, - 3428

From their experiments on sulphuric acid and water, - - 7262

Do. do. do. 2598
Do. from nitric acid and lime, + 23837
Dr. Irvine placed it below 30°, = 900
Dr. Crawford do. do. = 1500

The above result of Lavoisier and Laplace on nitric acid and lime, shows the theorem in a very absurd point of view, for it places the zero of cold, *above* melting platina. MM. Clement and Desormes have been lately searching after the absolute zero, and are convinced that it is at 266.66° below the zero of the centigrade scale, or — 448° F. This is a more conceivable result. But MM. Dulong and Petit have been led by their investigation to fix the absolute zero at infinity. "This opinion," say they, "rejected by a great many philosophers because it leads to the notion, that the quantity of heat in bodies is infinite, supposing their capacity constant, becomes probable, now that we know that the specific heats diminish as the temperatures sink. In fact the law of this diminution may be such, that the integral of heat, taken to a temperature infinitely low, may notwithstanding have a finite value." They farther infer, that the quantity of heat developed at the instant of the combination of bodies has no relation to the capacity of the elements; and that in the greatest number of cases this loss of heat is not followed by any diminution in the capacity of the compounds formed. This consequence of their researches, if correct, is fatal to the theorem of Irvine, and to all the inferences that have been drawn from it.

3. *Of the general habitudes of heat, with the different forms of matter.*

The effects of heat are either transient and physical; or permanent and chemical, inducing a durable change in the constitution of bodies. The second mode of operation we shall treat of under COMBUSTION. The first falls to be discussed here; and divides itself naturally into the two heads, of changes in the volume of bodies while they retain their form, and changes in the state of bodies.

1st, The successive increments of volume which bodies receive with successive increments of temperature, have been the subjects of innumerable researches. The expansion of fluids is so much greater than that of solids by the same elevation of their temperature, that it becomes an easy task to ascertain within certain limits the augmentation of volume which liquids and gases suffer through a moderate thermometric range. We have only to enclose them in a glass vessel of a proper form, and expose it to heat. But to determine their expansions with final accuracy, and free the results from the errors arising from the unequable expansion of the recipient, is a problem of no small difficulty. It seems, however, after many vain attempts by preceding experimenters, to have been finally solved by MM. Dulong and Petit. The expansion of solids had been previously measured with considerable accuracy by several philosophers, particularly by Smeaton, Roy, Ramsden, and Troughton, in this country, and Lavoisier and Laplace in France. The method devised by Genl. Roy, and executed by him in conjunction with Ramsden, deserves the preference. The metallic or other rod, the subject of experiment, was placed horizontally in a rectangular trough of water, which could be conveniently heated. At any aliquot distance on the rod, two micrometer microscopes were attached at right angles, so that each being adjusted at first to two immoveable points, exterior to the heating apparatus, when the rod was elongated by heat, the displacement of the microscopes could be determined to a very minute quantity, to the twenty or thirty thousandth of an inch, by the micrometrical mechanism.

The apparatus of Lavoisier and Laplace was on Smeaton's plan, a series of levers; but differed in this respect, that the last lever gave a vertical motion to a telescope of six feet focal length, whose quantity of displacement was determined by a scale in its field of view from 100 to 200 yards distant. This addition of a micrometrical telescope was ingenious; but the whole mechanism is liable to many objections, from which that of Ramsden was free. Still, when managed by such hands and heads as those of Lavoisier and Laplace, we must regard its results with veneration. MM. Dulong and Petit have measured the dilatations of some solids, as well as mercury, on plans which merit equal praise for their originality and philosophical precision. They commenced with mercury. Their method with it is founded on this incontestable law of hydrostatics, that when two columns of a liquid communicate by means of a lateral tube, the vertical heights of these two columns are precisely the inverse of their densities. In the axis of two upright copper cylinders, vertical tubes of glass were fixed, joined together at bottom by an horizontal glass tube resting on a levelled iron bar. One of the cylinders was charged with ice, the other with oil to be warmed at pleasure by a subjacent stove. The rectangular inverted glass syphon was filled nearly to the top with mercury, and the height at which the liquid stood in each leg was determined with nicety by a telescopic micrometer, revolving in a horizontal plane on a vertical rod. The telescope had a spirit level attached to it, and could be moved up or down a very minute quantity by a fine screw. The temperature of the oil, the medium of heat, was measured by both an air and a mercurial thermometer, whose bulbs occupied nearly the whole vertical extent of the cylinder. The elongation of the heated column of mercury could be rigorously known by directing the eye through the micrometer, first to its surface, and next to that in the ice-cold leg. Having by a series of careful trials ascertained the expansions of mercury through different thermometric ranges, they then determined the expansion of glass from the apparent expansions of mercury within it. They filled a thermometer with well boiled mercury, and plunging it into ice, waited till the liquid became stationary, and then cut across the stem at the point where the mercury stood. After weighing it exactly, they immersed it for some time in boiling water. On withdrawing, wiping, and weighing it, they learned the quantity of mercury expelled, which being compared with the whole weight of the mercury in it at the temperature of melting ice, gave the dilatation of volume. This is precisely the plan employed long ago by Mr. Crighton, as well as myself, and which gave the quantity 1-63d, employed in my paper for the apparent dilatation of mercury in glass.

Their next project was to measure the dilatation of other solids; and this they accomplished with much ingenuity by enclosing a cylinder of the solid, iron for example, in a glass tube, which was filled up with mercury, after its point had been drawn out to a capillary point. The mercury having been previously boiled in it, to expel all air and moisture, the tube was exposed to different temperatures. By determining the weight of the mercury which was driven out, it was easy to deduce the dilatation of the iron; for the volume driven out obviously represents the sum of the dilatations of the mercury and the metal, diminished by the dilatation of the glass. To make the calculation, it is necessary to know the volumes of these three bodies at the temperature of freezing water; but that of the iron is obtained by dividing its weight by its density at 32°. We deduce in the same manner the volume of the glass from the quantity of mercury which fills it at that temperature. That of the mercury is obviously the difference of the first two. The process just pointed out may be applied likewise to other metals, taking the precaution merely to oxidize their surface to hinder amalgamation.

In the years 1812 and 1813 I made many experiments with a micrometrical apparatus of a peculiar construction, for measuring the dilatation of solids. I was particularly perplexed with the rods of zinc, which after innumerable trials I finally found to elongate permanently by being alternately heated and cooled. It would seem that the plates composing this metal, in sliding over each other by the expansive force of heat, present such an adhesive friction as to prevent their entire retraction. It would be desirable to know the limit of this effect, and to see what other metals are subject to the same change. I hope to be able ere long to finish these pyrometrical researches.

I shall now present a copious table of dilatations, newly compiled from the best experiments.

TABLE I.—*Linear Dilatation of Solids by Heat.*

		Dimensions which a bar takes at 212°, whose length at 32° is 1.000000.	Dilatation in Vulgar Fractions.
Glass tube,	Smeaton, - -	1.00083333	
do.	Roy, - - -	1.00077615	
do.	Deluc's mean, -	1.00082800	
do.	Dulong and Petit,	1.00086130	$\frac{1}{1116}$
do.	Lavoisier and Laplace,	1.00081166	$\frac{1}{1148}$
Plate glass,	do. do.	1.000890890	$\frac{1}{1122}$
do. crown glass,	do. do.	1.00087572	$\frac{1}{1142}$
do. do.	do. do.	1.00089760	$\frac{1}{1114}$
do. do.	do. do.	1.00091751	$\frac{1}{1090}$
do. rod,	Roy,	1.00080787	
Deal,	Roy, as glass, -	....	
Platina,	Borda, - -	1.00085655	
do.	Dulong and Petit,	1.00088420	$\frac{1}{1131}$
do.	Troughton, - -	1.00099180	
do. and glass,	Berthoud, - -	1.00110000	
Palladium,	Wollaston, - -	1.00100000	
Antimony,	Smeaton, - -	1.00108300	
Cast iron prism,	Roy, - - -	1.00110940	
Cast iron,	Lavoisier, by Dr. Young,	1.00111111	
Steel,	Troughton, -	1.00118990	
Steel rod,	Roy, - -	1.00114470	
Blistered steel,	Phil. Trans. 1795. 428,	1.00112500	
do.	Smeaton, - -	1.00115000	
Steel not tempered,	Lavoisier and Laplace,	1.00107875	$\frac{1}{927}$
do. do. do.	do. do.	1.00107956	$\frac{1}{926}$
do. tempered yellow,	do. do.	1.00136900	
do. do. do.	do. do.	1.00138600	
do. do. do. at a higher heat,	do. do.	1.00123956	$\frac{1}{807}$
Steel,	Troughton, -	1.00118980	
Hard steel,	Smeaton, - -	1.00122500	
Annealed steel,	Muschenbroek, -	1.00122000	
Tempered steel,	do. -	1.00137000	
Iron,	Borda, - -	1.00115600	
do.	Smeaton, -	1.00125800	
Soft iron forged,	Lavoisier and Laplace,	1.0012204	
Round iron, wire-drawn,	do. do.	1.00123504	
Iron wire,	Troughton, -	1.00144010	
Iron,	Dulong and Petit,	1.00118203	$\frac{1}{846}$
Bismuth,	Smeaton, - -	1.00139200	
Annealed gold,	Muschenbroek, -	1.00146000	
Gold,	Ellicot, by comparison,	1.00150000	
do. procured by parting,	Lavoisier and Laplace,	1.00146606	$\frac{1}{682}$
do. Paris standard, unannealed.	do. do.	1.00155155	$\frac{1}{645}$
do. do. annealed,	do. do.	1.00151361	$\frac{1}{661}$
Copper,	Muschenbroek, -	1.0019100	
do.	Lavoisier and Laplace,	1.00172244	$\frac{1}{581}$
do.	do. do.	1.00171222	$\frac{1}{584}$
do.	Troughton, -	1.00191880	
do.	Dulong and Petit,	1.00171821	$\frac{1}{582}$
Brass,	Borda, - -	1.00178300	
do.	Lavoisier and Laplace,	1.00186671	
do.	do. do.	1.00188971	

Brass scale, supposed from Hamburgh,	Roy, - -	1.00185540	
Cast brass,	Smeaton, - -	1.00187500	
English plate-brass, in rod,	Roy, - -	1.00189280	
do. do. in a trough form,	do. - -	1.00189490	
Brass,	Troughton, -	1.00191880	
Brass wire,	Smeaton, - -	1.00193000	
Brass,	Muschenbroek, -	1.00216000	
Copper 8, tin 1,	Smeaton, - -	1.00181700	
Silver,	Herbert, - -	1.00189000	
do.	Ellicot, by comparison,	1.0021000	
do.	Muschenbroek, -	1.00212000	
do. of cupel,	Lavoisier and Laplace,	1.00190974	$\frac{1}{524}$
do. Paris standard,	do. do.	1.00190868	$\frac{1}{524}$
Silver,	Troughton, -	1.0020826	
Brass 16, tin 1,	Smeaton, - -	1.00190800	
Speculum metal,	do. - -	1.00193300	
Spelter solder; brass 2, zinc 1,	do. - -	1.00205800	
Malacca tin,	Lavoisier and Laplace,	1.00193765	$\frac{1}{516}$
Tin from Falmouth,	do. do.	1.00217298	$\frac{1}{462}$
Fine pewter,	Smeaton, - -	1.00228300	
Grain tin,	do. - -	1.00248300	
Tin,	Muschenbroek, -	1.00284000	
Soft solder; lead 2, tin 1,	Smeaton, - -	1.00250800	
Zinc 8, tin 1, a little hammered,	do. - -	1.00269200	
Lead,	Lavoisier and Laplace,	1.00284836	$\frac{1}{351}$
do.	Smeaton, - -	1.00286700	
Zinc,	do. - -	1.00294200	
Zinc, hammered out ½ inch per foot,	Smeaton, - -	1.00301100	
Glass, from 32°, to 212°,	Dulong and Petit,	1.00086130	$\frac{1}{1161}$
do. from 212°, to 392°,	do. do.	1.00091827	$\frac{1}{1083}$
do. from 392°, to 572°,	do. do.	1.00101114	$\frac{1}{987}$

The last two measurements by an air thermometer.

To obtain the expansion in volume, multiply the above decimal quantities by three, or divide the denominators of the vulgar fractions by three; the quotient in either case is the dilatation sought.

We see that a condensed metal, one whose particles have been forcibly approximated by the wire-drawing process, expands more, as might be expected, than metals in a looser state of aggregation. The result for pewter, I conceive, must be inaccurate. Lead ought to communicate to tin, surely, a greater expansive property. Borda's measure of platina is important. It was observed with the *rules* which served for measuring the base of the trigonometrical survey in France. The observations in the table on tempered steel, are, I believe, by that eminent artist, Fortin, though they are included in the table which M. Biot published, under the title of Lavoisier and Laplace.

The amount of the dilatation of metals becomes very useful to determine, in certain cases, the change of dimension to which astronomical instruments are liable. Thus in measuring a base for the grand operation of the meridian of France, Borda sought to elude the uncertainties arising from expansion of the measuring rods, by combining metallic bars, so that they indicated, of themselves, their variations of temperature, and of length. A rule of platina, twelve feet long, was attached by one of its extremities to a rule of copper somewhat shorter, which rested freely on its surface, when placed in a horizontal position. Towards the loose end of the copper rule, there was traced on the platina rule very exact linear divisions, the parts of which were millionths of the total length of this rule. The end of the copper rule carried a vernier, whose coincidences with the platina graduations were observed with a microscope. Now, the dilatations of the platina and copper being unequal for equal changes of temperature, we may conceive that the vernier of the copper rule would incessantly correspond to variable divisions, according as the temperatures varied. Borda made use of these changes, to know at every instant the common temperature of these two bars, and the ratio of the absolute dilatations of their two metals. The value of the vernier divisions had been previously ascertained, by plunging the compound bar into water of different temperatures, contained in an oblong wooden trough. It was therefore sufficient to read the indications of this metallic thermometer, in order to learn the true temperature of the bars in the atmosphere; and of course the compensation to be made on the *meter* rods or chains, to bring them to the true length of the standard temperature.

An exact acquaintance with the dilatation of metals, is also necessary for regulating the length of the pendulum in astronomical clocks. When the ball or bob of a seconds pendulum is let down $\frac{1}{100}$ of an inch, the clock will go ten seconds slower in 24 hours; and therefore $\frac{1}{1000}$ of an inch, will make it lose one second per day. Now, as the effective length of the seconds pendulum is 39.13929 inches, we know from the previous table of expansion, that a change of 30° of temperature by Fahrenheit's scale, will alter its length about $\frac{1}{5000}$ part, which is equivalent to nearly 0.0078, or $\frac{1}{128}$ of an inch, corresponding to about eight seconds of error in the day. The first, the most simple, and most perfect invention for obviating these variations, is due to Graham. The bob of his compensation pendulum consisted of a glass cylinder, about six inches long, holding ten or twelve pounds of mercury. In proportion as the iron or steel rod to which this was suspended, dilated by heat, the mercury also expanded, and raised thereby the centre of oscillation, just as much as the lengthening of the rod had depressed it. M. Biot, with his usual accuracy, has shown, that if the suspending rod were of glass, the length of the cylinder of mercury would require to be $\frac{1}{10}$ the total length of the pendulum, namely, about four inches; but the expansion of iron being greater in the ratio, pretty nearly of three to two, we have hence the length of the cylinder in the latter case, equal to about six inches. The late very ingenious Mr. Gavin Lowe, prescribed along with a steel rod, a glass cylinder two inches diameter inside, containing $6\frac{4}{10}$ vertical inches of mercury, weighing ten pounds. From accurate calculation he found, that if such a pendulum should go perfectly true, when the thermometer is at 30°, but that at 90° it should go one second slower in 24 hours, it would be remedied by pouring in ten ounces more quicksilver; or, by taking out that quantity, if it went one second faster in 24 hours, when at 90° than at 30° Fahr.; and for $\frac{1}{10}$ of a second of deviation in 24 hours, the compensation is the addition or abstraction of one ounce of mercury. See a useful paper on this subject, by Mr. Firminger, in the Philosophical Magazine for August 1819.

The balance wheel of a watch, varies in the time of its oscillations, by its expansions and contractions with variations of temperature. The invention of Arnold furnished a wheel or interrupted ring, composed of concentric laminæ of two metals, which, obviating the above defect by their difference of dilatation, has, under the name of compensation balance, incalculably improved the accuracy of marine chronometers. We shall describe under THERMOMETER, an elegant instrument constructed on similar principles, by the celebrated M. Breguet. See other applications, *infra.*

TABLE II.—*Dilatation of the volume of* LIQUIDS *by being heated from* 32° *to* 212°.

Mercury,	Dalton,	0.020000	$\frac{1}{50}$
do.	Lord Charles Cavendish,	0.018870	$\frac{1}{53}$
do.	Deluc,	0.018000	$\frac{1}{56}$
do.	General Roy,	0.017000	$\frac{1}{59}$
do.	Shuckburgh,	0.01851	$\frac{1}{54}$
do.	Lavoisier and Laplace,	0.01810	$\frac{1}{55.22}$
do.	Haellstroem,	0.0181800	$\frac{1}{55}$
do.	Dulong and Petit,	0.0180180	$\frac{1}{55.50}$
do.	do. from 212°, to 392°,	0.0184331	$\frac{1}{54.25}$
do.	do. from 392°, to 572°,	0.0188700	$\frac{1}{53}$
do.	do. in glass, from 32°, to 212°,	0.015432	$\frac{1}{64.8}$
do.	do. do. from 212°, to 392°,	0.015680	$\frac{1}{63.78}$
do.	do. do. from 392°, to 572°,	0.0158280	$\frac{1}{63.18}$
Water,	Kirwan, from 39°, its maximum density,	0.04332	$\frac{1}{23.08}$
Muriatic acid, (sp. gr. 1.137),	Dalton,	0.0600	$\frac{1}{17}$
Nitric acid. (sp. gr. 1.40),	do.	0.1100	$\frac{1}{9}$
Sulphuric acid, (sp. gr. 1.85),	do.	0.0600	$\frac{1}{17}$
Alcohol,	do.	0.1100	$\frac{1}{9}$
Water,	do.	0.0460	$\frac{1}{22}$
Water saturated with common salt,	do.	0.0500	$\frac{1}{20}$
Sulphuric ether,	do.	0.0700	$\frac{1}{14}$
Fixed oils,	do.	0.0800	$\frac{1}{12.5}$

Oil of turpentine,	do.	0.0700	$\frac{1}{14}$
The quantities given by Mr. Dalton, are probably too great, as is certainly the case with mercury; his experiments being perhaps modified by his hypothetical notions,			
Water saturated with common salt, Robinson,		0.05198	$\frac{1}{19}$

Dr. Young, in his invaluable *Catalogue raisonnée*, Natural Philosophy, vol. ii. p. 391. gives the following table of the expansions of water, constructed from a collation of experiments by Gilpin, Kirwan, and Achard. He says, that the degrees of Fahrenheit's thermometer, reckoning either way from 39° being called f, the expansion of water is nearly expressed by $22f^2\ (1-.002f)$ in 10 millionths; and the diminution of the specific gravity by $.0000022f^2-00000000472f^3$. This equation, as well as the table, are very important for the reduction of specific gravities of bodies, taken by weighing them in water.

	Sp. grav.		*Dimin. of sp. gr.*	*Expansion.*
30°	0.99980		0.00020	
32	0.99988		0.00012	
34	0.99994		0.00006	
39	1.00000		0.00000	
44	0.99994		0.00006	
48	0.99982		0.00018	
49	0.99978		0.00022	
54	0.99951		0.00049	
59	0.99914		0.00086	
60°	0.99906		0.00094	
64	0.99867		0.00133	
69	0.99812		0.00188	
74	0.99749		0.00251	
(77°)	0.99701	Achard		0.00299
79	0.99680	Gilpin	0.00320	0.00321
(82)	0.99612	Kirwan	0.00388	0.00389
90	0.99511	Gilpin	0.00489	0.00491
100	0.99313		0.00687	0.00692
102	0.99246	Kirwan	0.00754	0.00760
122	0.98757		0.01243	0.01258
	0.98872	Deluc	0.01128	
142	0.98199	K.	0.01801	0.01833
162	0.97583		0.02417	0.02481
167	0.97480	Deluc	0.02520	
182	0.96900	K.	0 03100	0.03198
202	0.96145		0.03855	0.04005
212	0.95848		0.04152	0.04333

Deluc introduced into a series of thermometer glasses, the following liquids, and noted their comparative indications by expansion at different degrees of heat, measuring on Reaumur's thermometer, of which 80° is the boiling point of water, and 0° the melting point of ice.

TABLE of Thermometric Indications by DELUC.

Mercury.			*Olive Oil.*	*Es. Oil of Chamomile.*	*Oil of Thyme.*	*Alcohol.*	*Brine.*	*Water.*
R.	*Cent.*	*Fahr.*						
80°	100°	212°	80°	80°	80°	80°	80°	80°
75	93¾	200¾	74.6	74.7	74.3	73.8	74.1	71
70	87.5	189½	69.4	69.5	68.8	67.8	68.4	62
65	81.	178¼	64.4	64.3	63.5	61.9	62.6	53.5
60	75.	167	59.3	59.1	58.3	56.2	57.1	45.8
55	68¾	155¾	54.2	53.9	53.3	50.7	51.7	38.5
50	62½	144½	49.2	48.8	48.3	45.3	46.6	32.
45	56¼	133¼	44.0	43.6	43.4	40.2	41·2	26.1
40	50	122	39.2	38.6	38.4	35.1	36.3	20.5
35	43¾	110¾	34.2	33.6	33.5	30.3	31.3	15.9
30	37½	99½	29.3	28.7	28.6	25.6	26.5	11.2
25	31¼	88¼	24.3	23.8	23.8	21.0	21.9	7.3
20	25	77	19.3	18.9	19.0	16.5	17.3	4.1
15	18¾	65¾	14.4	14.1	14.2	12.2	12.8	1.6
10	12½	54½	9.5	9.3	9.4	7.9	8.4	0.2
5	6¼	43¼	4.7	4.6	4.7	3.9	4.2	0.4
0	0	32	0.0	0.0	0.0	0.0	0.0	0,0
— 5	6¼	20¾				—3.9	—4.1	
—10	12½	9½				—7.7	—8.1	

As I consider these results of Deluc valuable, in so far as they enable us to compare directly the expansions in glass of these different thermometric liquids, I have added the two columns marked Cent. and Fahr. to give at once the reductions to the centigrade and Fahrenheit graduation. The alcohol was of such strength that its flame kindled gunpowder, and it was found that the results were not much changed by a small difference in the strength of the spirit. The brine was water saturated with common salt.

M. Biot, in the first volume of his elaborate *Traité de Physique*, has investigated several empyrical formulæ, to represent the laws of dilatation of the different fluids. They are too complex for a work of this nature. He shows that for all liquids whose dilatations have been hitherto observed, the general march of this dilatation may be represented at every temperature by an expression of this form, ${}^{\delta}t = at + bt^2 + ct^3$, in which t denotes the temperature in degrees of the mercurial thermometer; $a\ b\ c$ constant coefficients, which depend on the nature of the liquid, and ${}^{\delta}t$ the true dilatation for the volume 1.0 from the temperature of melting ice. We shall content ourselves with giving one example, from which we may judge of the great geometrical resources of this philosopher. For olive oil the formula becomes ${}^{D}T = 0.95067\ T + 0.00075\ T^2 - 0.000001667\ T^3$.

The following table gives its results compared with experiment.

Of the mercurial.	*Calculated.*	*Observed.*
80°	80°	80°
70	69.64	69.41
60°	59.37°	59.3°
50	49.2	49.2
40	39.12	39.2
30	29.15	29.3
20	19.30	19.3
10	9.58	9.5
	0.0	0.

M. Gay-Lussac has lately endeavoured to discover some law which should correspond with the rate of dilatation of *different* liquids by heat. For this purpose, instead of comparing the dilatations of different liquids, above or below a temperature uniform for all, he set out from a point variable with regard to temperature, but uniform as to the cohesion of the particles of the bodies; namely, from the point at which each liquid boils under a given pressure. Among those which he examined, he found two which dilate equally from that point, viz. alcohol and sulphuret of carbon, of which the former boils at 173.14°, the latter at 115.9° Fahr. The other liquids did not present, in this respect, the same resemblance. Another analogy of the above two liquids is, that the same volume of each gives, at its boiling point, under the same atmospheric pressure, the same volume of vapour; or in other words, that the densities of their vapours are to each other as those of the liquids at their respective boiling temperatures. The following table shows the results of this distinguished chemist.

TABLE of the Contractions of 1000 *parts in volume, by cooling.*

	Water.		*Alcohol.*		*Sulphuret of Carb.*		*Ether.*	
	Contract by exp't.	*Ditto calculated.*	*Contract by exp't*	*Ditto calculated.*	*Contract by exp't.*	*Ditto calculated.*	*Contract by exp't.*	*Ditto calculated.*
Boiling.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
— 5°	3.34	3.35	5.55	5.56	6.14	6.07	8.15	8.16
—10	6.61	6.65	11.43	11.24	12.01	12.08	16.17	16.01
—15	10.50	9.89	17.51	17.00	17.98	17.99	24.16	23.60
—20	13.15	13.03	24.34	23.41	23.80	23.80	31.83	30.92
—25	16.06	16.06	29.15	28.60	29.65	29.50	39.14	38.08
—30	18.85	18.95	34.74	34.37	35.06	35.05	46.42	45.04
—35	21.52	21.67	40.28	40.05	40.48	40.43	52.06	51.86
—40	24.10	24.20	45.68	45.66	45.77	45.67	58.77	58.77
—45	26.50	26.52	50.85	51.11	51.08	50.70	65.48	65.20
—50	28.56	28.61	56.02	56.37	56.28	55.52	72.01	71.79
—55	30.60	30.43	61.01	61.43	61.14	60.12	78.38	78.36
—60	32.42	31.96	65.96	66.23	66.21	64.48		
—65	34.02	33.19	10.74	70.75				
—70	35.47	34.09	75.48	74.93				
—75	36.70	34.63	80.11	78.75				

Their respective boiling points are:

Water, -	100° Cent.	= 212° F.
Alcohol, - -	78.41	173
Sulphuret of carb.	46.60	126
Sulphuric ether,	35.66	96

The experiments were made in thermometer vessels, hermetically sealed.

Alcohol, at 78.41° cent. produces 488.3 its vol. of vapour.

Sulphuret of carbon, at 46.60° cent. produces 491.1 its vol. of vapour.

Ether, at 35.66° cent. produces 285.9 its vol. of vapour.

Water, at 100.00° cent. produces 1633.1 its vol. of vapour.

Dr. Thomson, treating of expansion, states, that "different kinds of glass differ so much from each other, that no general rule can be laid down."—System, vol. i. page 73. This statement is at variance with the results of MM. Dulong and Petit, as well as of my own pyrometrical measurements. "Nor have we found," say these accurate observers, "any appreciable difference between the effects observed in tubes of ordinary glass obtained from different manufactories, whatever was their calibre or their thickness." I believe the differences to have arisen from the errors of the previous pyrometrical measurements, applied to a body whose dilatation is so small. Thus General Roy, perhaps the most accurate of all experimenters, found at one time, that a glass tube expanded four times as much as a rod; and he afterwards found; on the contrary, that the rod expanded more than the tube by about $\frac{1}{25}$, the glass being from the same pot. I found, that a rod and tube made out of the same glass pot expanded the same quantity, through a range of 400° Fahr.; and believe, that such crystal or flint-glass as is used in Great Britain for chemical purposes, is wonderfully uniform in its rate of dilatation by heat, through the same portions of the thermometric scale. Nor are the differences considerable between the expansions of crown and plate glass.

The different rate of expansion which liquids undergo, by the same degree of temperature, has been theorized upon by Dr. Thomson; and as this is the only example in his writings in which he has ventured to propound an original philosophical law, it is entitled to examination.

"The expansion of liquid bodies differs from that of the elastic fluids, not only in quantity, but in the want of uniformity with which they expand, when equal additions are made to the temperature of each. This difference seems to depend upon the fixity or volatility of the component parts of the liquid bodies; for in general those liquids expand most by a given addition of heat whose boiling temperatures are lowest, or which contain in them an ingredient which readily assumes the gaseous form. Thus mercury expands much less when heated to a given temperature than water, which boils at a heat much inferior to mercury; and alcohol is much more expanded than water, because its boiling temperature is lower. In like manner, nitric acid is much more expanded than sulphuric acid, not only because its boiling point is lower, but because a portion of it has a tendency to assume the form of an elastic fluid. This rule holds at least in all the liquids whose expansions I have hitherto tried. We may consider it therefore as a pretty general fact, that the higher the temperature necessary to cause a liquid to boil, the smaller the expansion is which is produced by the addition of a degree of heat; or, in other words, the expansibility of liquids is nearly inversely as their boiling temperatures."—*Thomson's Chemistry, 5th edition*, vol. i. pp. 66 and 67.

After enforcing, in such varied expressions, his new law, that the lower the boiling point of a liquid is, the greater is its expansibility by heat, one would not expect to find it completely abrogated and set at nought, by a table of experimental results in the very same page. Yet such is the fact, as its quotation will prove.

"The following table exhibits the dilatation of various liquids, from the temperature of 32° to that of 212°, supposing their bulk at 32° to be 1.

"Alcohol, - -	0.1100 = $\frac{1}{9}$	"boiling point,	174°
Nitric acid, (sp. gr. 1.40) -	0.1100 = $\frac{1}{9}$	ditto	247
Fixed oils, - -	0.080 = $\frac{1}{12}$	ditto	600
Sulphuric ether, - -	0.070 = $\frac{1}{14}$	ditto	98
Oil of turpentine, - -	0.070 = $\frac{1}{14}$	ditto	314
Muriatic acid, (sp. gr. 1.137.)	0.060 = $\frac{1}{17}$	ditto	217
Sulphuric acid, (sp. gr. 1.85.)	0.060 = $\frac{1}{17}$	ditto	620
Water saturated with common salt,	0.05 = $\frac{1}{20}$	ditto	225
Water, - - -	0.0466 = $\frac{1}{22}$	ditto	212
Mercury, - -	0.02 = $\frac{1}{50}$"	ditto	656"

I have added the boiling points as set down in his System. We here remark that alcohol and nitric acid have the same rate of expansion affixed, though the distances of their respective boiling points from 32° are as 2 to 3. But the most amusing illustration of the *converse* of Dr. Thomson's law, is presented by himself with regard to fixed oil and ether, the former having the *greater* expansion, though its boiling point is about *ten times* more distant in thermometric degrees, than that of ether, from 32°. Ether and oil of turpentine expand the same proportion, and yet their boiling points differ by 216°. But muriatic acid and sulphuric acid also expand the same quantity, though their boiling points, and "their tendencies to assume the form of an elastic fluid" are exceedingly different. Finally, water expands *less* than sulphuric acid, while its boiling temperature is greatly *lower*. Had Dr. Thomson propounded the very reverse proposition, viz. that the rate of expansion in liquids is *higher* the *higher* their boiling temperatures, he would have encountered fewer contradictory facts, though still enow to explode the *generality* of the principle. In a philosophical system of chemistry, examples of such false reasoning are injurious to the student, and lower the rank of the science.

Mercury in its expansions, follows the rate of fluid metals, and therefore is not properly comparable to oily, watery, or spirituous liquids. It is curious that one of the examples which Dr. Thomson adduces to illustrate his pretended rule, which "holds, he says, at least in all the liquids whose expansion I have hitherto tried," actually breaks it; for alcohol expands fully a half more than ether; and yet, the interval from its boiling point to 32°, is more than double that interval in ether, instead of being greatly less as his law requires. Since his table obviously disqualifies water, alcohol, ether, oils, and acids, from constituting such a series in expansion, as his rule requires, one may naturally ask this celebrated chemist, what are "the liquids whose expansion he has hitherto tried?

In solid metals, the expansion seems to be greater, the less their tenacity and density, though to this general position, we have striking exceptions in antimony and bismuth, provided they were accurately measured by Smeaton's apparatus, of which, however, I have reason to doubt. The least flexure in the expanding rods, will evidently make the expansions come out too small. If metallic dilatability vary with some unknown function of density and tenacity, as is probable *a priori*, we would expect their rate of expansion to increase with the temperature. This view coincides with the following results of MM. Dulong and Petit.

Temperatures by dilatation of air.	*Expansions in bulk of*		
	Iron.	*Cop.*	*Plat.*
0° to 100°, cent. give	$\frac{1}{282}$	$\frac{1}{194}$	$\frac{1}{377}$
0° to 300°, mean quantity,	$\frac{1}{227}$	$\frac{1}{177}$	$\frac{1}{363}$

Tripling these denominators, we have the linear expansions, fractionally expressed, thus:

	Iron.	*Cop.*	*Plat.*
0° to 100° cent.	$\frac{1}{846}$	$\frac{1}{582}$	$\frac{1}{1131}$
0° to 300°, mean,	$\frac{1}{681}$	$\frac{1}{531}$	$\frac{1}{1089}$

To multiply inductive generalizations, that is, to groupe together *facts* which have some important qualities common to them all, is the main scope and business of philosophy. But to imagine phenomena, or to twist real phenomena into a shape suited to a preconceived constitution of things, was the vice of the Peripatetic schools, which Bacon so admirably exposed; of which in our times and studies, according to MM. Dulong and Petit, Mr. Dalton's speculations on the laws of heat, afford a striking example.

Mr. Dalton has the merit of having first proved that the expansions of all aeriform bodies, when insulated from liquids, are uniform by the same increase of temperature; a fact of great importance to practical chemistry, which was fully verified by the independent and equally original researches of M. Gay-Lussac on the subject, with a more refined and exact apparatus. The latter philosopher demonstrated, that 100 in volume at 32° Fahr. or 0° cent. become 1.375 at 212° Fahr. or 100 cent. Hence the increment of bulk for each degree F. is $\frac{0\cdot375}{180} = 0.002083 = \frac{1}{480}$; and for the centigrade scale it is $\frac{0\cdot375}{100} = = 0.00375 = \frac{1}{266\cdot6}$. To reduce any volume of gas, therefore, to the bulk it would occupy at any standard temperature, we must multiply the thermometric difference in degrees of Fahr. by 0.002083, or $\frac{1}{480}$, subtracting the product from the given volume, if the gas be heated above, but adding it, if the gas be cooled below, the standard temperature. Thus 25 cubic inches at 120° Fahrenheit will at 60° occupy a volume of $21\frac{7}{8}$; for $\frac{1}{480} \times 60 = \frac{60}{480} = \frac{1}{8}$; and $\frac{25}{8} = 3\frac{1}{8}$, which, taken from 25, leaves $21\frac{7}{8}$. A table of reduction will be found under Gas. When the table is expressed decimally, indeed, to 6 or 7 figures, it becomes more troublesome to apply than the above rule. Vapours, when heated out of contact of their respective liquids, obey the same law as gases, a discovery due to M. Gay-Lussac.

We shall now treat of the anomaly presented by water in its dilatations by change of temperature, and then conclude this part of the subject with some practical applications of the preceding facts.

The Florentine academicians, and after them Dr. Croune, observed, that on cooling in ice and salt, the bulb of a thermometric glass vessel filled with water, the liquid progressively sunk in the stem, till a certain point, after which the further progress of refrigeration was accompanied by an ascent of the liquid, indicating expansion of the water. This curious phenomenon was first accurately studied by M. De Luc, who placed the apparent term of greatest density at 40° Fahr., and considered the expansion of water from that point, to vary with equal amount, by an equal change of temperature, whether of increase or decrease. Having omitted to make the requisite correction for the effect of the expansion of the glass in which the water was contained, it was found afterwards by Sir Charles Blagden and Mr. Gilpin, who introduced this correction, that the *real* term of greatest density was 39° F.

The following Table gives their Experimental results.

Specific Gravity	*Bulk of Water.*	*Temperature.*		*Bulk of water.*	*Specific Gravity.*
	1.00000	39°		1.00000	
1.00000	1.00000	38	40	1.00000	1.00000
0.99999	1.00001	37	41	1.00001	0.99999
0.99998	1.00002	36	42	1.00002	0.99998
0.99996	1.00004	35	43	1.00004	0.99996
0.99994	1.00006	34	44	1.00006	0.99994
0.99991	1.00008	33	45	1.00009	0.99991
0.99988	1.00012	32	46	1.00012	0.99988

By weighing a cylinder of copper and of glass in water at different temperatures, the maximum density comes out 40° F. Finally Dr. Hope, in 1804, published a set of experiments in the Edin. Phil. Trans. in which the complication introduced into the question by the expansion of solids, is very philosophically removed. He shows that water exposed in tall cylindrical vessels, to a freezing atmosphere, precipitates to the bottom its colder particles, till the temperature of the mass sinks to 39.5° F. after which the colder particles are found at the surface. He varied the form of the experiment by applying a zone of ice, round the top, middle, and bottom of the cylinders; and in each case, delicate thermometers placed at the surface and bottom of the water, indicated that the temperature 39.5°, coincided with the maximum density. We may therefore regard the point of 40°, adopted by the French, in settling their standard of weights and measures, as sufficiently exact.

The force with which solids and liquids expand or contract by heat and cold, is so prodigiously great as to overcome the strongest obstacles. Some years ago it was observed at the *Conservatoire des arts et metiers* at Paris, that the two side walls of a gallery were receding from each other, being pressed outwards by the weight of the roof and floors. Several holes were made in each of the walls, opposite to one another, and at equal distances, through which strong iron bars were introduced so as to traverse the chamber. Their ends outside of the wall were furnished with thick iron discs, firmly screwed on These were sufficient to retain the walls in their actual position. But to bring them nearer together would have surpassed every effort of human strength. All the alternate bars of the series were now heated at once by lamps, in consequence of which they were elongated. The exterior discs being thus freed from contact of the walls, permitted them to be advanced farther, on the screwed ends of the bars. On removing the lamps, the bars cooled, contracted, and drew in the opposite walls. The other bars became in consequence loose at their extremities, and permitted their end plates to be further screwed on. The first series of bars being again heated, the above process was repeated in each of its steps. By a succession of these experiments they restored the walls to the perpendicular position; and could easily have reversed their curvature inwards, if they had chosen. The gallery still exists with its bars, to attest the ingenuity of its preserver M. Molard.

2d, Of the change of *state* produced in bodies by caloric, independent of change of *composition*. The three forms of matter, the solid, liquid, and gaseous, seem immediately referable to the power of heat, modifying, balancing, or subduing cohesive attraction. In the article *blow-pipe*, we have shown that every solid may be liquefied, and many of them, as well as all liquids, may be vaporized at a certain elevation of temperature. And conversely almost every known liquid may be solidified by the reduction of its temperature. If we have not hitherto been able to convert the air and other elastic fluids into liquids or solids, it is probably owing to the limited power we possess over thermometric depression. But we know, that by mechanical approximation of their elastic particles, an immense evolution of heat is occasioned, which must convince us that their gaseity is intimately dependent on the operation of that repulsive power.

Sulphuric ether, always a liquid in our climate, if exposed to the rigors of a Siberian winter, would become a solid, and, transported to the torrid zone, would form a permanent gas. The same transitions are familiar to us with regard to water, only its vaporizing point, being much higher, leads us at first to suppose steam an unnatural condition. But by generalizing our ideas, we learn that there is really no state of bodies which can be called more natural than another. Solidity, liquidity, the state of vapours and gases, are only accidents connected with a particular level of temperature. If we pass the easily condensed vapour of nitric acid through a red-hot glass tube, we shall convert it into gases which are incondensable by any degree of cold which we can command. The particles which formed the liquid can no longer join together to reproduce it, because their distances are changed, and with these have also changed the reciprocal attractions which united them.

Were our planet removed much further from the sun, liquids and gases would solidify; were it brought nearer that luminary, the bodies which appear to us the most solid, would be reduced into thin invisible air. We see, then, that the principle of heat, whatever it may be, whether matter or quality, separates the particles of bodies when its energy augments, and suffers them to approach when its power is enfeebled. By extending this view, it has been drawn into a general conclusion, that this principle was itself the force which maintains the particles of bodies *in equilibrio* against the effort of their reciprocal attraction, which tends continually to bring them together. But although this conclusion be extremely probable, we must remember that it is hypothetical, and goes further than the facts. We see that the force which balances attraction in bodies may be favoured or opposed by the principle of heat, but this does not necessarily prove that these forces are of the same nature.

The instant of equilibrium which separates the solid from the liquid state, deserves consideration. Whatever may be the cause and law of the attractions which the particles exercise on one another, the effect which results ought to be modified by their forms. When all the other qualities are equal, a particle which may be cylindrical, for example, will not exercise the same attraction as a sphere, on a point placed at an equal distance from its centre of gravity. Thus in the law of celestial gravitation, the attraction of an ellipsoid on an exterior point, will be stronger in the direction of its smaller than in that of its larger axis, at the same distance from its surface. Now whatever be the law of attractions which holds together the particles of bodies, similar differences must exist. These particles must be attracted more strongly by certain sides than by others. Thence must result differences in the manner of their arrangement, when they are sufficiently approximated for their attractions to overcome the repulsive power. This explains to us in a very probable manner, the regular crystallization which most solid bodies assume, when they concrete undisturbed. We may easily conceive how the different substance of the particles, as well as their different forms, may produce in crystals all the varieties which we observe.

The system of the world presents magnificent effects of this attraction dependent on figure. Such are the phenomena of nutation and the precession of the equinoxes, produced by the attractions of the sun and moon on the flattened spheroid of the earth. These sublime phenomena would not have existed, had the earth been a sphere; they are connected with its oblateness and rotation, in a manner which may be mathematically deduced, and subjected to calculation.

But the investigation shows, that this part of the attraction dependent on figure, decreases more rapidly than the principal force. The latter diminishes as the square of the distance; the part dependent on figure diminishes as the cube of the distance. Thus also, in the attractions which hold the parts of bodies united, we ought to expect an analogous difference to occur. Hence the force of crystallization may be subdued, before the principal attractive force is overcome. When the particles are brought to this distance, they will be indifferent to all the positions which they can assume round their centre of gravity; this will constitute the liquid condition. Suppose now that the temperature falling, the particles approach slowly to each other, and tend to solidify anew; then the forces dependent on their figure will come again into play, and in proportion as they increase, the particles solicited by these forces will take movements round their centres of gravity. They will turn towards each other their faces of greatest attraction, to arrive finally at the positions which their crystallization demands. Now according to the figure of the particles, we may conceive that these movements may react on their centre of gravity, and cause them to approach or recede gradually from each other, till they finally give to their assemblage the volume due to the solid state; a volume which in certain cases may be greater, and in others smaller, than that which they occupied as liquids. These mechanical considerations thus explain, in the most probable and satisfactory manner, the dilatations and contractions of an irregular kind, which certain liquids, such as water and mercury, experience, on approaching the term of their congelation. Having given these general views, we may now content ourselves with stating the facts as much as possible in a tabular form.

TABLE of the Concreting or Congealing Temperatures of various Liquids, by FAHRENHEIT'S *Scale.*

Sulphuric ether,		— 46°
Liquid ammonia,		— 46
Nitric acid, sp. gr.	1.424	— 45.5
Sulphuric acid, sp. gr.	1.6415	— 45
Mercury,		— 39
Nitric acid, sp. gr.	1.407	— 30.1
Sulphuric acid,	1.8064	— 26
Nitric acid,	1.3880	— 18.1
Do. do.	1.2583	— 17.7
Do. do.	1.3290	— 2.4
Brandy,		— 7.0
Sulphuric acid,	1.8376	+ 1.
Pure prussic acid,		4 to 5
Common salt,	25 + water 75	4
Do.	22.2 + do. 77.8	7.2
Sal ammoniac,	20 + do. 80	8
C. salt,	20 + do. 80	9.5
Do.	16.1 + do. 83.9	13.5
Oil of turpentine,		14.
Strong wines,		20
Rochelle salt,	50 + water 50	21.
C. salt,	10 + do. 90	21.5
Oil of bergamot,		23
Blood,		25
C. salt,	6.25 + water 93.75	25.5
Eps salts,	41.6 + do. 58.4	25.5
Nitre,	12.5 + do. 87.5	26.
C. salt,	4.16 + do. 95.84	27.5
Copperas,	41.6 + do. 58.4	28
Vinegar,		28
Sul. of zinc,	53.3 + water 46.7	28.6
Milk,		30
Water,		32
Olive oil,		36
Sulphur and phosphorus, eq. parts,		40
Sulphuric acid, sp. gr.	1.741	42
Do. do.	1.780	46
Oil of anise,		50
Concentrated acetic acid,		50
Tallow, Dr. Thomson,		92
Phosphorus,		108
Stearin from hog's lard,		109
Spermaceti,		112
Tallow, Nicholson,		127
Margaric acid,		134
Potassium,		136.4
Yellow wax,		142
Do. Do.		149
White wax,		155
Sodium,		194
Sulphur, Dr. Thomson,		218
Do. Dr. Hope,		234
Tin,		442
Bismuth,		476
Lead,		612
Zinc, by Sir H. Davy,		680
Zink, Brongniart,		698°
Antimony,		809?

See PYROMETER for higher heats.

The solidifying temperature of the bodies above tallow, in the table, is usually called their freezing or congealing point; and of tallow and the bodies below it, the fusing or melting point. Now, though these temperatures be stated, opposite to some of the articles, to *fractions* of a thermometric degree, it must be observed, that various circumstances modify the concreting point of the liquids, through *several* degrees; but the *liquefying* points of the same bodies, when once solidified, are uniform and fixed, to the preceding temperatures.

The preliminary remarks which we offered on the forces concerned in the transition from liquidity to solidity, will in some measure explain these variations; and we shall now illustrate them by some instructive examples.

If we fill a narrow-mouthed matrass with newly distilled water, and expose it very gradually to a temperature considerably below 32°, the liquid water will be observed, by the thermometer left in it, to have sunk 10 or 11 degrees below its usual point of congelation. M. Gay-Lussac, by covering the surface of the water with oil, has caused it to cool 21½ degrees Fahr. below the ordinary freezing temperature. Its volume at the same time expanded as much as if it had been heated 21½ degrees above 32°. According to Sir Charles Blagden, to whom the first of these two observations belongs, its dilatation may amount to 1-7th of the total enlargement, which it receives by solidifying. Absolute repose of the liquid particles is not necessary to ensure the above phenomenon, for Sir Charles stirred water at 21° without causing it to freeze, but the least vibration of their mass, or the application of icy spiculæ, by the atmosphere, or the hand, determines an instantaneous congelation.

We may remark here, that the dilatation of the water increasing as it cools, but to a less extent than when it concretes, is a proof that its constituent particles, in obedience to the cooling process, turn their poles more and more towards the position of the maximum attraction, which constitutes their solid state. But this position may be determined instantaneously by the ready formed aqueous solid, the particles of which presenting themselves to those of the liquid, by their sides of greatest attraction, will compel them to turn into similar positions. Then the particles of the liquid first reverted will act on their neighbours like the exterior crystal, and thus from point to point the movement will be propagated through the whole mass, till all be congealed. The vibratory movements act by throwing the particles, into positions favorable for their mutual attraction.

The very same phenomena occur with saline solutions. If a hot saturated solution of Glauber's salt be cooled to 50° under a film of oil, it will remain liquid, and will bear to be moved about in the hand without any change; but if the phial containing it be placed on a vibrating table, crystallization will instantly take place. In a paper on saline crystallization which I published in the 9th number of the Journal of Science, I gave the following illustration of the above phenomena. "The effect of mechanical disturbance in determining crystallization, is illustrated by the symmetrical disposition of particles of dust and iron, by electricity and magnetism. Strew these upon a plane, and present magnetic and electric forces at a certain distance from it, no effect will be produced. Communicate to the plane a vibrating movement; the particles, at the instant of being liberated from the friction of the surface, will arrange themselves according to the laws of their respective magnetic or electric attractions. The water of solution in counteracting solidity, not only removes the particles to distances beyond the sphere of mutual attraction, but probably also inverts their attracting poles." Perhaps the term *avert* would be more appropriate to liquidity, to denote an obliquity of direction in the attracting poles; and *revert* might be applied to gaseity, when a repulsive state succeeds to the feebly attractive powers of liquid particles.

The above table presents some interesting particulars relative to the acids. I have expressed their strengths, by specific gravity, from my tables of the acids, instead of by the quantity of marble which 1000 grains of them could dissolve, in the original statement of Mr. Cavendish. Under the heads of nitric acid and equivalent, some observations will be found on these peculiarities with regard to congelation. We see that common salt possesses the greatest efficacy in counteracting the congelation of water; and next to it, sal ammoniac. Mr. Crighton of Glasgow, whose accuracy of observation is well known, has remarked, that when a mass of melted bismuth cools in the air, its temperature falls regularly to 468°, from which term it however instantly springs up to 476°, at which point it remains till the whole be consolidated. Tin in like manner sinks and then rises 4 degrees; while melted lead, in cooling, becomes stationary whenever it descends to 612°. We shall presently find the probable cause of these curious phenomena.

Water, all crystallizable solutions, and the three metals, cast-iron, bismuth, and antimony, expand considerably in volume, at the instant of solidification. The greatest obstacles cannot resist the exertion of this expansive force. Thus glass bottles, trunks of trees ,iron and lead pipes, even mountain rocks, are burst by the dilatation of the water in their cavities, when it is converted into ice. In the same way our pavements are raised in winter. The beneficial operation of this cause is exemplified in the comminution or loosening the texture of dense clay soils, by the winter's frost, whereby the delicate fibres of plants can easily penetrate them. Major Williams of Quebec, burst bombs, which were filled with water and plugged up, by exposing them to a freezing cold.

There is an important circumstance occurs in the preceding experiments on the sudden congelation of a body kept liquid below its usual congealing temperature, to which we must now advert. The mass, at the moment its crystallization commences, rises in temperature to the term marked in the preceding table, whatever number of degrees it may have previously sunk below it. Suppose a globe of water suspended in an atmosphere at 21° F.; the liquid will cool and remain stationary at this temperature, till vibration of the vessel, or contact of a spicula of ice, determines its concretion, when it instantly becomes 11 degrees hotter than the surrounding medium. We owe the explanation of this fact, and its extension to many analogous chemical phenomena, to the sagacity of Dr. Black. His truly philosophical mind was particularly struck by the slowness with which a mass of ice liquefies when placed in a genial atmosphere. A lump of ice at 22° freely suspended in a room heated to 50°, which will rise to 32° in 5 minutes, will take 14 times 5, or 70 minutes, to melt into water, whose temperature will be only 32°. Dr. Black suspended in an apartment two glass globes of the same size alongside of each other, one of which was filled with ice at 32°, the other with water at 33°. In half an hour the water had risen to 40°; but it took 10½ hours to liquefy the ice and heat the resulting water to 40° Both these experiments concur therefore in showing that the fusion of ice is accompanied with the expenditure of 140 degrees of calorific energy, which have no effect on the thermometer. For the first experiment tells us that 10 degrees of heat entered the ice in the space of 5 minutes, and yet 14 times that period passed in its liquefaction. The second experiment shows that 7 degrees of heat entered the globes in half an hour; but 21 half hours were required for the fusion of the ice, and for heating of its water to 40°. If from the product of 7 into 21 = 147, we subtract the 7 degrees which the water was above 33, we have 140 as before. But the most simple and decisive experiment is to mingle a pound of ice in small fragments with a pound of water at 172°. Its liquefaction is instantly accomplished, but the temperature of the mixture is only 32°. Therefore 140° of heat seem to have disappeared. Had we mixed a pound of ice-cold water with a pound of water at 172°, the resulting temperature would have been 102°, proving that the 70° which had left the hotter portion, were manifestly transferred to that which was cooler The converse of the preceding experiments may also be demonstrated; for in suspending a flask of water, at 35° for example, in an atmosphere at 20°, if it cool to 32° in 3 minutes, it will take 140 minutes to be converted into ice of 32°; because the heat emanating at the rate of 1° per minute, it will require that time for 140° to escape. The latter experiment, however, from the inferior conducting power of ice, and the uncertainty when all is frozen is not susceptible of the precision which the one immediately preceding admits. The tenth of 140 is obviously 14; and hence we may infer that when a certain quantity of water, cooled to 22°, or 10°, below 32°, is suddenly caused to congeal, 1-14th of the weight will become solid.

We can now understand how the thaw which supervenes after an intense frost, should so slowly melt the wreaths of snow, and beds of ice, a phenomenon observable in these latitudes from the origin of time, but whose explanation was reserved for Dr. Black. Indeed, had the transition of water from its solid into its liquid state not been accompanied by this great change in its relation to heat, every thaw would have occasioned a frightful inundation, and a single night's frost would have solidified our rivers and lakes. Neither animal nor vegetable life could have subsisted under such sudden and violent transitions. Mr. Cavendish, who had discovered the above fact, before he knew of its being inculcated by Dr. Black in his lectures, states the quantity of heat which ice seems to absorb in its fusion to be 150°; Lavoisier and Laplace make it 135°: a number probably correct, from the pains they took in constructing, on this basis, their calorimeter. The fixity of the melting points of bodies exposed to a strong heat need no longer surprise us; because till the whole mass be melted, the heat incessantly introduced, is wholly expended in constituting liquidity, without increasing the temperature. We can also comprehend how a liquid metal, a saline solution, or water, should in the career of refrigeration, sink below the term of its congelation, and suddenly remount to it. Those substances, in which the attractive force that reverts the poles into the solid arrangement acts most slowly or feebly, will most readily permit this depression of temperature, before liquidity begins to cease. Thus bismuth, a brittle metal, takes 8° of cooling below its melting point, to determine its solidification; tin takes 4°, but lead passes so readily into the solid arrangement that its cooling is at once arrested at its fusing temperature. In illustration of this statement, we may remark, that the particles of bismuth and tin lose their cohesive attraction in a great measure long before they are heated to the melting point; though lead continues relatively cohesive till it begins to melt. Tin may be easily pulverized at a moderate elevation of temperature, and bismuth in its cold state. The instant, however, that these two metals, when melted, begin to congeal, they rise to the proper fusing temperature, because the caloric of liquidity is then disengaged.

Drs. Irvine, father and son, to both of whom the science of heat is deeply indebted, investigated the proportion of caloric disengaged by several other bodies in their passage from the liquid to the solid state, and obtained the following results:

	Caloric of liquidity.	*Do. referred to the sp. heat of water.*
Sulphur,	143.68	27.14
Spermaceti,	145.	
Lead,	162.	5.6
Bees wax,	175.	
Zinc,	493.	48.3
Tin,	500.	33.
Bismuth,	550	23.25

The quantities in the second column are the degrees by which the temperatures of each of the bodies in its solid state, would have been raised by the heat disengaged during its concretion. An exception must be made for wax and spermaceti; which are supposed to be in the fluid state, when indicating the above elevation. Dr. Black imagined that the new relation to heat which solids acquire by liquefaction, was derived from the absorption, and intimate combination of a portion of that fluid, which thus employing all its repulsive energies in subduing the stubborn force of cohesion, ceased to have any thermometric tension, or to be perceptible to our senses. He termed this supposed quantity of caloric, their *latent* heat; a term very convenient and proper, while we regard it simply as expressing the relation which the calorific agent bears to the same body in its fluid and solid states. To the presence of a certain portion of latent or combined heat in solids, Dr. Black ascribed their peculiar degrees of softness, toughness, malleability. Thus we know that the condensation of a metal by the hammer, or under the die, never fails to render it brittle, while, at the same time, heat is disengaged. Berthollet subjected equal pieces of copper and silver to repeated strokes of a fly press. The elevation of their temperature, which was considerable by the first blow, diminished greatly at each succeeding one, and became insensible whenever the condensation of volume ceased. The copper suffered greatest condensation, and evolved most heat. Here the analogy of a sponge, yielding its water to pressure, has been employed to illustrate the materiality of heat supposed deducible from these experiments. But the phenomenon may be referred to the intestine actions between the ultimate particles which must accompany the violent dislocation of their attracting poles. The cohesiveness of the metal is greatly impaired.

The enlarged capacity for heat, to use the popular expression, which solids acquire in liquefying, enables us to understand and apply the process of artificial cooling, by what are called freezing mixtures. When two solids, such as ice and salt, by their reciprocal affinity, give birth to a liquid, then a very great demand for heat is made on the surrounding bodies; or they are powerfully stripped of their heat, and their temperature sinks of course. Pulverulent snow and salt mixed at 32°, will produce a depression of the thermometer plunged into them of about 38°. The more rapid the liquefaction, the greater the cold. Hence the paradoxical experiment of setting a pan on the fire containing the above freezing mixture with a small vessel of water plunged into it. In a few seconds the water will be found to be frozen. The solution of all crystallized salts is attended with a depression of temperature, which increases generally with the solubility of the salt.

The table of freezing mixtures in the Appendix, presents a copious choice of such means of refrigeration. Equal parts of sal ammoniac and nitre, in powder, form the most convenient mixture for procuring moderate refrigeration; because the water of solution being afterwards removed by evaporation, the pulverized salts are equally efficacious as at first. Under the articles Climate, Congelation, Temperature, Thermometer, and Water, some additional facts will be found on the present subject.

But the diminution of temperature by liquefaction is not confined to saline bodies. When a solid amalgam of bismuth, and a solid amalgam of lead, are mixed together, they become fluid, and the thermometer sinks during the time of their action.

The equilibrium between the attractive and repulsive forces which constitutes the liquid condition of bodies, is totally subverted by a definite elevation of temperature, when the external compressing forces do not vary. The transition from the liquid state into that of elastic fluidity is usually accompanied with certain explosive movements, termed ebullition. The peculiar temperatures at which different liquids undergo this change is therefore called their boiling point; and the resulting elastic fluid is termed a *vapour*, to distinguish it from a *gas*, a substance permanently elastic, and not condensable as vapours are, by moderate degrees of refrigeration. It is evident that when the attractive forces, however feeble in a liquid, are supplanted by strong repulsive powers, the distances between the particles must be greatly enlarged. Thus a cubic inch of water at 40° becomes a cubic inch and 1-25th on the verge of 212°, and at 212° it is converted into 1600 cubic inches of steam. The existence of this steam indicates a balance between its elastic force and the pressure of the atmosphere. If the latter be increased beyond its average quantity by natural or artificial means, then the elasticity of the steam will be partially overcome, and a portion of it will return to the liquid condition. And conversely, if the pressure of the air be less than its mean quantity, liquids will assume elastic fluidity by a less intensity of calorific repulsion, or at a lower thermometric tension. Professor Robison performed a set of ingenious experiments, which appear to prove, that when the atmospheric pressure is wholly withdrawn, that is, in *vacuo*, liquids become elastic fluids 124° below their usual boiling points. Hence water *in vacuo* will boil and distil over at 212° — 124 = 88° Fahr. This principle was long ago employed by the celebrated Watt in his researches on the steam engine, and has been recently applied in a very ingenious way by Mr. Tritton in his patent still, (Phil. Mag. vol. 51.), and Mr. Barry, in his evaporator for vegetable extracts, (Med. Chir. Trans. vol. 10). See Alcohol, Distillation, Extracts.

On the same principle of the boiling, varying with the atmospheric pressure, the Rev. Mr. Wollaston has constructed his beautiful thermometric barometer for measuring heights. He finds that a difference of 1° in the boiling point of water is occasioned by a difference of 0.589 of an inch on the barometer. This corresponds to nearly 520 feet of difference of elevation. By using the judicious directions which he has given, the elevation of a place may thus be rigorously determined, and with great convenience. The whole apparatus, weighing 20 ounces, packs in a cylindrical tin case, 2 inches diameter, and 10 inches long.

When a vessel containing water is placed over a flame. a hissing sound or simmering is soon perceived. This is ascribed to the vibrations occasioned by the successive vaporization and condensation of the particles in immediate contact with the bottom of the vessel. The sound becomes louder as the liquid is heated, and terminates in ebullition. The temperature becomes now of a sudden stationary when the vessel is open, however rapidly it rose before, and whatever force of fire be applied. Dr. Black set a tin cup full of water at 50°, on a red hot iron plate. In four minutes it reached the boiling point, and in twenty minutes it was all boiled off. From 50° to 212°, the elevation is 162°; which interval, divided by 4, gives 40½° of heat, which entered the tin cup *per* minute. Hence 20 minutes, or 5 times 4 multiplied into 40½ = 810, will represent the quantity of heat that passed into the boiling water to convert it into a vapour. But the temperature of this is still only 212°. Hence, according to Black, these 810° have been expended solely in giving elastic tension, or, according to Irvine, in supplying the vastly increased capacity of of the aeriform state; and therefore they may be denominated latent heat, being insensible to the thermometer. The more exact experiments of Mr. Watt have shown, that whatever period be assigned for the heating of a mass of water from 50° to 212°, 6 times this period is requisite with a uniform heat for its total vaporization. But 6 × 162° = 972 = the latent heat of steam; a result which accords with my experiments made in a different way, as will be presently shown. Every attentive operator must have observed the greater explosive violence and apparent difficulty of the ebullition of water exposed to a similar heat in glass, than in metallic vessels. M. Gay-Lussac has studied this subject with his characteristic sagacity. He discovered that water boiling in a glass vessel has a temperature of 214.2°, and in a tin vessel contiguous to it, of only 212°. A few particles of pounded glass thrown into the former vessel, reduces the thermometer plunged in it to 212.6, and iron filings to 212. When the flame is withdrawn for a few seconds from under a glass vessel of boiling water, the ebullition will recommence on throwing in a pinch of iron filings.

Professors Munche and Gmelin of Heidelberg have extended these researches, and given the curious results as to the boiling points, expressed in the following table:

Substance of the vessels.	*Ther. touching bottom.*	*Do. ½ inch below surface of the water.*
Silver,	211.775°	211. 55°
Platina,	211.775	210.875
Copper,	212.900	212.225
Tinned iron,	213. 24	211. 66
Marble,	212. 10	211. 66
Lead,	212. 45	211.775
Tin,	212. 7	211.775
Porcelain,	212. 1	211.900
White glass,	212. 7	212. 00
Green glass,	213. 8	213. 35
Ditto,	212. 7°	212. 00°
Delft ware,	213. 8	212. 7
Common earthen ware	213. 8	212. 45

It is difficult to reconcile these variations to the results of M. Gay-Lussac. "The vapour formed at the surface of a liquid," he remarks, "may be *in equilibrio* with the atmospheric pressure; while the interior portion may acquire a greater degree of heat than that of the real boiling point, provided the fluid be enclosed in a vessel, and heated at the bottom. In this case, the adhesion of the fluid to the vessel may be considered as analogous in its action to viscidity, in raising the temperature of ebullition. On this principle we explain the sudden starts which sometimes take place in the boiling of fluids. This frequently occurs to a great degree in distilling sulphuric acid, by which the vessels are not unfrequently broken when they are of glass. This evil may be effectually obviated by putting into the retort some small pieces of platina wire, when the sudden disengagement of gas will be prevented and consequently the vessels not be liable to be broken."—*Annales de Chimie*, March 1818. See my remarks on this subject under the DISTILLATION of SULPHURIC ACID, extracted from the Journal of Science, October 1817. If we throw a piece of paper, a crust of bread, or a powder, into a liquid slightly impregnated with carbonic acid, its evolution will be determined. See some curious observations by M. Thenard under our articles OXYGENIZED NITRIC ACID, or OXYGENIZED WATER. In a similar manner, the asperities of the surface of a glass or other vessel, act like points in electricity, in throwing off gas or vapour present in the liquid which it contains.

In all the examples of the preceding table, the temperature is greater at the bottom than near the surface of the liquid; and the specific differences must be ascribed to the attractive force of the vessel to water, and its conduction of heat. We must thus try to explain why tinned iron gives a temperature to boiling water in contact with it, 1.67 degrees higher than silver and platina. Between water, and iron, tin, or lead, there are reciprocal relations at elevated temperatures, which do not apparently exist with regard to silver and platina.

The following is a tabular view of the boiling points by Fahrenheit's scale of the most important liquids, under a mean barometrical pressure of thirty inches:—

		Boiling points.
Ether, sp. gr. 0.7365 at 48°.	G. Lussac,	100°
Carburet of sulphur, -	do.	113
Alcohol, sp. gr. 0.813	Ure,	173.5
Nitric acid, 1.500	Dalton,	210
Water, ...		212
Saturated sol. of Glaub. salt.	Biot, -	213⅓

			Boiling points.
Saturated sol. of sugar of lead,		Biot,	$215\frac{2}{3}$°
Do. do. sea salt,		do.	$224\frac{1}{3}$
Muriate of lime 2 + water 1		Ure,	230
Do.	35.5 + do. 64.5	do.	235
Do.	40.5 + do. 59.5	do.	240
Muriatic acid,	1.094	Dalton,	232
Do.	1.127	do.	222
Do.	1.047	do.	222
Nitric acid,	1.45	do.	240
Do.	1.42	do.	248
Do.	1.40	do.	247
Do.	1.35	do.	242
Do.	1.30	do.	236
Do.	1.16	do.	220
Rectified petroleum,		Ure,	306
Oil of turpentine,		do.	316
Sulp. acid sp. gr.	1.30 +	Dalton,	240
Do.	1.408	do.	260
Do.	1.520	do.	290
Do.	1.650	do.	350
Do.	1.670	do.	360
Do.	1.699	do.	374
Do.	1.730	do.	391
Do.	1.780	do.	435
Do.	1.810	do.	473
Do.	1.819	do.	487
Do.	1.827	do.	501
Do.	1.833	do.	515
Do.	1.842	do.	545
Do.	1.847	do.	575
Do.	1.848	do.	590
Do.	1.849	do.	605
Do.	1.850	do.	620
Do.	1.848	Ure,	600
Phosphorus,			554
Sulphur,			570
Linseed oil,			640?
Mercury, (Dulong, 662°),			656

These liquids emit vapours, which, at their respective boiling points, balance a pressure of the atmosphere, equivalent to thirty vertical inches of mercury. But at inferior temperatures they yield vapours of inferior elastic power. It is thus that the vapour of quicksilver rises into the vacuum of the barometer tube; as is seen particularly in warm climates, by the mercurial dew on the glass at its summit. Hence aqueous moistures adhering to the mercury, causes it to fall below the true barometer level, by a quantity proportional to the temperature. The determination of the elastic force of vapours, in contact with their respective liquids, at different temperatures, has been the subject of many experiments. The method of measuring their elasticities, described in my paper on Heat, seems convenient, and susceptible of precision.

A glass tube about one-third of an inch internal diameter, and 6 feet long, is sealed at one end, and bent with a round curvature in the middle, into the form of a syphon, with its two legs parallel, and about 2½ inches asunder. A rectangular piece of cork is adapted to the interval between the legs, and fixed firmly by twine, about 6 inches from the ends of the syphon. Dry mercury is now introduced, so as to fill the sealed leg, and the bottom of the curvature. On suspending this syphon barometer in a vertical direction, by the cork, the level of the mercury will take a position in each of the legs, corresponding to the pressure of the atmosphere. The difference is of course the true height of the barometer at the time, which may be measured by the application of a separate scale of inches and tenths. Fix rings of fine platinum wire round the tube at the two levels of the mercury. Introduce now into the tube a few drops of distilled water, recently boiled, and pass them up through the mercury. The vapour rising from the water will depress the level of the mercury in the sealed leg, and raise it in the open leg, by a quantity equal in each to one-half of the real depression. To measure distinctly this difference of level with minute accuracy, would be difficult; but the total depression, which is the quantity sought, may be readily found, by pouring mercury in a slender stream into the open leg, till the surface of the mercury in the sealed leg becomes once more a tangent to the platina ring, which is shewn by a delicate film of light, as in the mountain barometer. The vertical column of mercury above the lower initial level being measured, it represents precisely the elastic force of the vapour, since that altitude of mercury was required to overcome the elasticity of the vapour. The whole object now is to apply a regulated heat to the upper portion of the sealed leg, from an inch below the mercurial level, to its summit. This is easily accomplished, by passing it through a perforated cork into an inverted phial, '5 inches diameter and 7 long, whose bottom has been previously cracked off by a hot iron. Or a phial may be made on purpose. When the tapering elastic cork is now strongly pressed into the mouth of the bottle, it renders it perfectly water-tight. By inclining the syphon, we remove a little of the mercury, so that when reverted, the level in the lower leg may nearly coincide with the ring. Having then suspended it in the vertical position from a high frame, or the roof of an apartment, we introduce water at 32° into the cylindrical glass vessel. When its central tube, against the side of which the bulb of a delicate thermometer rests, acquires the temperature of the surrounding medium, mercury is slowly added to the open leg, till the primitive level is restored at the upper platina ring. The column of mercury above the ring in the open leg, is equivalent to the force of aqueous vapour at 32°. The effect of lower temperatures may be examined, by putting saline freezing mixtures in the cylinder. To procure measures of elastic force at higher temperatures, two feeble Argand flames are made to send up heated air, on the opposite shoulders of the cylinder. By adjusting the flames, and agitating the liquid, very uniform temperatures may be given to the tube in the axis. At every 5° or 10° of elevation, we make a measurement by pouring mercury into the open leg, till the primitive level is restored in the other.

For temperatures above 212°, I employ the same plan of apparatus, slightly modified. The sealed leg of the syphon has a length of 6 or 7 inches, while the open leg is 10 or 12 feet long, secured in the groove of a graduated wooden prism. The initial level becomes 212° when the mercury in each leg is in a horizontal plane, and the heat is now communicated through the medium of oil. If the bending of the tube, be made to an angle of about 35° from parallelism of the legs, a tubulated globular receiver becomes a convenient vessel for holding the oil. The tapering cork through which the sealed end of the syphon is passed, being thrust into the tapering mouth of the receiver, remains perfectly tight at all higher temperatures, being progressively swelled with the heat. One who has not made such trials, may be disposed to cavil at the probable tightness of such a contrivance, but I who have used it in experiments for many months together, know that only extreme awkwardness in the operator, can occasion the dropping out of oil heated up to even 320° of Fahrenheit. The tubulure of the receiver admits the thermometer. The Tables of Vapour, in the Appendix, exhibit the results of some carefully conducted experiments.

In my attempts to find some ratio which would connect the above elasticities of aqueous vapour with the temperatures, the following rule occurred to me:

"The elastic force at 212° = 30 being divided by 1.23, will give the force for 10° below; this quotient divided by 1.24, will give that 10° lower, and so on progressively. To obtain the forces above 212°, we have merely to multiply 30 by the ratio 1.23 for the force at 222°; this product by 1.22 for that at 232°, this last product by 1.21 for the force at 242°, and thus for each successive interval of 10° above the boiling point." The following modification of the same rule gives more accurate results. "Let r = the mean ratio between that of 210° and the given temperature; n = the number of terms (each of 10°) distant from 210°; F = the elastic force of steam in inches of mercury. Then Log. of F = Log. 28.9 $\pm$ n Log. r; the positive sign being used above, the negative below 210°." I have investigated also simple ratios, which express the connexion between the temperature and elasticity of the vapours of alcohol, ether, petroleum, and oil of turpentine, for which I must refer to the paper itself.

Mr. W. Creighton of Soho communicated in March 1819, to the Philosophical Magazine, the following ingenious formula for aqueous vapour. "Let the degrees of Fahrenheit + 85 = D, and the corresponding force of steam in inches of mercury − 0.09 = I. Then Log. D − 2.22679 × 6 = Log. I.

EXAMPLE.

$$\begin{array}{rrl}
212^\circ + 85 = 297 \text{ Log.} = & 2.47276 & \\
- & 2.22679 & \text{constant} \\
\hline
& & \text{number.} \\
& 0.24579 & \\
\times & 6 & \\
\hline
\text{Log.} & 1.47582 = 29.91 = \text{I} & \\
& +0.09 & \\
\hline
& \text{Inches } 30.00 \text{ D} &
\end{array}$$

He then gives a satisfactory tabular view of the near correspondences between the results of his formula, and my experiments.

By determining experimentally the volume of vapour which a given volume of liquid can produce at 212°, M. Gay-Lussac has happily solved the very difficult problem of the specific gravity of vapours. He took a spherule of thin glass, with a short capillary stem, and of a known weight. He filled it with the peculiar liquid, hermetically sealed the orifice, and weighed it. Deducting from its whole weight the known weight of the spherule, he knew the weight, and from its sp. gravity the bulk of the liquid. He filled a tall graduated glass receiver, capable of holding about three pints, with mercury, inverted it in a basin, and let up the spherule. The receiver was now surrounded by a bottomless cylinder, which rested at its lower edge in the mercury of the basin. The interval between the two cylinders was filled with water. Heat was applied by means of a convenient bath, till the water and the included mercury assumed the temperature of 212°. The expansible liquid had ere this burst the spherule, expanded into vapour, and depressed the mercury. The height of the quicksilver column in the graduated cylinder above the level of the basin, being observed, it was easy to calculate the volume of the incumbent vapour. The quantity of liquid used was always so small, that the whole of it was converted into vapour.

The following exhibits the specific gravities as determined by the above method:

	Spec. Grav. Air = 1.		*Boiling point, Fahr.*
Vapour of water,	0.62349		212°
Hydroprussic acid,	0.94760		79.7
Absolute alcohol,	1.6050		173
Sulphuric ether,	2.5860		96
Hydriodic ether,	5.4749		148
Oil of turpentine,	5.0130		316
Carburet of sulphur,	2.6447		116
Muriatic ether,	2.2190	Thenard,	52

The above specific gravities are estimated under a barometric pressure of 29.92 inches.

M. Gay-Lussac has remarked, that when a liquid combination of alcohol and water, or alcohol and ether, is converted into vapour at 212° Fahr. or 100 cent., the volume is exactly the sum of what their separate volumes would have produced; so that the condensation by chemical action in the liquid state, ceases to operate in the gaseous. An equal volume of carburet of sulphur and absolute alcohol, at their respective boiling points of 173° and 126°, is said to yield each an equal quantity of vapour of the same density. A more explicit statement has been promised, and is perhaps required on this curious subject.

It appears, that a volume of water at 40° forms 1694 volumes of steam at 212°. The subsequent increase of the volume of steam, and of other vapours, out of the contact of their respective liquids, we formerly stated to be in the ratio of the expansion of gases, forming an addition to their volume of 3-8ths for every 180° Fahrenheit. We can now infer, both from this expansion of one measure into 1694, and from the table of the elastic forces of steam, the explosive violence of this agent at still higher temperatures, and the danger to be apprehended from the introduction of water into the close moulds, in which melted metal is to be poured. Hence, also, the formidable accidents which have happened, from a little water falling into heated oils. The little glass spherules, called candle bombs, exhibit the force of steam in a very striking manner; but the risk of particles of glass being driven into the eye, should cause their employment to be confined to prudent experimenters. Mr. Watt estimated the volumes of steam resulting from a volume of water at 1800; and in round numbers at 1728; a number differing little from the above determination of M. Gay-Lussac. Desagulier's estimate of 14000 was therefore extravagant.

It has been already mentioned, that the caloric of fluidity in steam surpasses that of an equal weight of boiling water by about 972°. This quantity, or the latent heat of steam, as it is called, is most conveniently determined, by transmitting a certain weight of it into a given weight of water, at a known temperature, and from the observed elevation of temperature in the liquid, deducing the heat evolved during condensation. Dr. Black, Mr. Watt, Lavoisier, Count Rumford, Clement, and Desormes, as well as myself, have published observations on the subject. "In this research I employed a very simple apparatus; and with proper management, I believe, it is capable of giving the absolute quantities of latent heat in different vapours, as exactly as more refined and complicated mechanisms. At any rate, it will afford comparative results with great precision. It consisted of a glass retort of very small dimensions with a short neck, inserted into a globular receiver of very thin glass, and about three inches in diameter. The globe was surrounded with a certain quantity of water at a known temperature, contained in a glass basin. 200 grains of the liquid, whose vapour was to be examined, were introduced into the retort, and rapidly distilled into the globe by the heat of an Argand lamp. The temperance of the air was 45°, that of the water in the basin from 42° to 43°, and the rise of temperature, occasioned by the condensation of the vapour, never exceeded that of the atmosphere by four degrees. By these means, as the communication of heat is very slow between bodies which differ little in temperature, I found that the air could exercise no perceptible influence on the water in the basin during the experiment, which was always completed in five or six minutes. A thermometer of great delicacy was continually moved through the water; and its indications were read off, by the aid of a lens, to small fractions of a degree.

"In all the early experiments of Dr. Black on the latent heat of common steam, the neglect of the above precautions introduced material errors into the estimate. Hence, that distinguished philosopher found the latent heat of steam to be no more than 800° or 810°. Mr. Watt afterwards determined it more nearly from 900 to 970°; Lavoisier and Laplace have made it 1000°, and Count Rumford 1040°.

"From the smallness of the retort in my mode of proceeding, the shortness of the neck, and its thorough insertion into the globe, we prevent condensation by the air *in transitu;* while the surface of the globe, and the mass of water being great, relative to the quantity of vapour employed, the heat is entirely transferred to the refrigeratory, where it is allowed to remain without apparent diminution for a few minutes.

"In numerous repetitions of the same experiment the accordances were excellent The following table contains the mean results. The water in the basin weighed in each case 32340 grs., and 200 grs. of each liquid was distilled over. The globe was held steadily in the centre of the globe by a slender ring fixed round the neck." For the arithmetical reductions I must refer to the paper itself. Dr. Thomson, in his comments on this part of my researches, observes, "It is obvious, that the latent heats determined in this way must be considerably below the truth. The method contrived by Count Rumford seems to me a good deal better. He cooled the water surrounding the globe 4° below the temperature of the room, and continued the distillation till the temperature of the water was exactly 4° above that of the room." Surely Dr. Thomson cannot have read the paper with attention, or he would have perceived the following sentence: "I found that the air could exercise no perceptible influence on the water in the basin during the experiment, which was always completed in five or six minutes." In fact, I left the glass basin of water repeatedly at a temperature of 4° above that of the room for double the duration of the experiment, and found scarcely a perceptible change in the thermometer immersed in it. This source of fallacy was sufficiently guarded against. But I have found since, that a compensation was due for the glass basin itself, which I omitted by accident to introduce into the arithmetical reductions. This would have raised the latent heat of water to very nearly 1000, and that of the other vapours in a proportional degree. I now give the original table, along with a corrected column:

Table of Latent Heat of Vapours.

		Corrected column.
Vapour of water, at its boiling point, - - - -	967°	1000°
Alcohol, sp. gr. 825, - - - -	442	457
Ether, boiling point 112°, - - - -	302.4	312.9
Petroleum, - - - - -	177.8	183.8
Oil of turpentine, - - - - -	177.8	183.8
Nitric acid, sp. gr. 1.494, boiling point 165°,	532.	550.
Liquid ammonia, sp. gr. 0.978, - - -	837.3	865.9
Vinegar, sp. gr. 1.007, - - -	875.0	903

"Aqueous vapour of an elastic force balancing the atmospheric pressure, has a specific gravity compared to air, by the accurate experiments of M. Gay-Lussac, of 10 to 16. For facility of comparison, let us call the steam of water unity, or 1.00; then the specific gravity of the vapour of pure ether is 4.00, while the specific gravity of the vapour of absolute alcohol is 2.60. But the vapour of ether, whose boiling point is not 100°, but 112°, like the above ether, contains some alcohol; hence we must accordingly diminish a little the specific gravity number of its vapour. It will then become, instead of 4.00, 3.55. Alcohol of 0.825 sp. gr. contains much water; sp. gr. of its vapour 2.30. That of water, as before unity, 1.00. The interstitial spaces in these vapours will therefore be inversely as these numbers, or $\frac{1}{355}$ for ether, $\frac{1}{230}$ for alcohol, $\frac{1}{100}$ for water. Hence, $\frac{1}{355}$ of latent heat, existing in ethereal vapour, will occupy a proportional space, be equally condensed, or possess the same tension with $\frac{1}{250}$ in alcoholic, and $\frac{1}{100}$ in aqueous vapour. A small modification will no doubt be introduced by the difference of the thermometric tensions, or sensible heats, under the same elastic force. Common steam, for example, may be considered as deriving its total elastic energy from the latent heat multiplied into the specific gravity + the thermometric tension.

"Hence, the elastic force of water, ether, and alcohol, are as follows:—

$$E_w = 970 \times 1.00 + 212° = 1182$$
$$E_e = 302 \times 3.55 + 112° = 1184$$
$$E_{al} = 440 \times 23.0 + 175° = 1185$$

Three equations, which yield, according to my general proposition, equal quantities. When the elastic forces of vapours are doubled, or when they sustain a double pressure, their interstices are proportionably diminished. We may consider them now, as in the condition of vapours possessed of greater specific gravities. Hence, the second portion of heat introduced to give double the elastic force need not be equal to the first, in order to produce the double tension.

"This view accords with the experiments of Mr. Watt, alluded to in the beginning of the memoir. He found, that the latent heat of steam is less when it is produced under a greater pressure, or in a more dense state; and greater when it is produced under a less pressure, or in a less dense state. Berthollet thinks this fact so unaccountable, that he has been willing to discard it altogether. Whether the view I have just opened, of the relation subsisting between the elastic force, density, and latent heat of different vapours, harmonize with chemical phenomena in general, I leave others to determine. It certainly agrees with that *unaccountable* fact. Whatever be the fate of the general law, now respectfully offered, the statement of Mr. Watt may be implicitly received, under the sanction of his acknowledged sagacity and candor." *Ure's Researches on Heat*, pp. 54 and 55.

As it is the vastly greater relation to heat, which steam possesses above water, that makes the boiling point of that liquid so perfectly stationary in open vessels, over the strongest fires, we may imagine that other vapours which have a smaller latent heat, may not be capable, by their formation, of keeping the ebullition of their respective liquids at a uniform temperature. I observed this variation of the boiling point actually to happen with oil of turpentine, petroleum and sulphuric acid. When these liquids are heated briskly in apothecaries' phials, they rise 20 or 30 degrees above the ordinary point, at which they boil in hemispherical capsules. Hence, also, their vapours being generated with little heat, are apt to rise with explosive violence. Oil of turpentine varies moreover, in its boiling point, according to its freshness and limpidity. It is needless, therefore, to raise an argument on a couple of degrees of difference. But, in Dr. Murray's, and all our other chemical systems, published prior to 1817, 560° was assigned as the boiling point of this volatile oil. Mr. Dalton's must be excepted, for he says, "several authors have it, that oil of turpentine boils at 560°. I do not know how the mistake originated, but it boils below 212°, like the rest of the essential oils." Dr. Thomson makes it 314°; a number which, from the great price he paid for his thermometer, he insinuates to be more exact than mine of 316°; and *a fortiori* than 320°, as found by the manufacturer of the oil, to whom I had referred. But the difference of our two numbers is in reality frivolous, and to be ascribed to the state of the oil and of the heat, as much as to errors of the instruments or of observation. It is probable that our thermometers were equally correct, and used with equal care. But what will Dr. Thomson say of Mr. Dalton's emendation?

From the above quotation it may be inferred, that the conversion at all temperatures, however low, of any liquid or solid whatever, into a vapour, is uniformly accompanied with the abstraction of heat from surrounding bodies, or in popular language, the production of cold; and that the degree of refrigeration will be proportional to the capacity of the vapour for heat, and the rapidity of its formation. The application of this principle to the uses of life, first suggested by Drs. Cullen and Black, has been improved and extended by Mr. Leslie. We shall describe his methods under CONGELATION.

It appears, moreover, probable, that the permanent gases have the same superior relation to heat with the vapours. Hence, their transition to the liquid or solid states ought to be attended with the evolution of heat. Accordingly, in the combustion of hydrogen, phosphorus, and metals, gaseous matter is copiously fixed; to which cause Black and Lavoisier ascribed the whole of the heat and light evolved. We shall see, however, in the article COMBUSTION, many difficulties to the adoption of this plausible hypothesis. The best illustration of the common notion as to the latent heat of gases, is afforded by the condensed air tinder-tube; in which mechanical compression appears to extrude from cold air its latent stores of both heat and light. A glass tube, eight inches long, and half inch wide, of uniform calibre, shut at one end, and fitted with a short piston, is best adapted for the exhibition of this pleasing experiment. When the object, however, is merely to kindle agaric-tinder, a brass tube 3-8ths wide and 4½ inches long will suffice. A dexterous condensation of air into 1-5th of the volume, produces the heat of ignition.

Under the head of specific heat, it has been shown to diminish in a gas, more rapidly than the diminution of its volume; and therefore, heat will be disengaged by its condensation, whether we regard the phenomenon as the expulsion of a fluid, or intense actions excited among the particles by their violent approximation. The converse of the above phenomenon is exhibited on a great scale, in the Schemnitz mines of Hungary. The hydraulic machine for draining them, consists essentially of two strong air-tight copper cylinders, 96 feet vertically distant from each other, and connected by a pipe. The uppermost, which is at the mouth of the pit, can be charged with water by the pressure of a reservoir, elevated 136 feet above it. The air suddenly dislodged by this vast hydrostatic pressure, is condensed through the pipe, on the surface of the water standing in the lower cylinder, which it forces up a rising water-pipe to the surface, and then takes its place. When the stop-cocks are turned to recharge the lower cylinder with water, the imprisoned air expanding to its natural volume, absorbs the heat so powerfully, as to convert the drops of water that issue with it, into hail and snow. M. Gay-Lussac has lately proposed a miniature imitation of this machine for artificial refrigeration. He exposes the small body to be cooled, to a stream of air escaping by a small orifice, from a box in which it had been strongly condensed. In the autumn of 1816, I performed an analogous experiment in the house of M. Breguet, in Paris. This celebrated artist having presented me with one of his elegant metallic thermometers, I immediately proposed to determine by means of it, the heat first abstracted, and subsequently disengaged, in the exhaustion of air, and its readmission into the receiver of an air-pump. MM. Breguet politely favoured me with their assistance, and the use of their excellent air-pump. Having enclosed in the receiver their thermometer, and a delicate one by Crighton, which I happened to have with me, we found, on rapidly exhausting the receiver, that M. Breguet's thermometer indicated a refrigeration of 50° F. while Crighton's sunk only 7°. After the two had arrived at the same temperature, the air was rapidly admitted into the receiver. M. Breguet's thermometer now rose 50°, while Crighton's mounted 7° as before. See THERMOMETER.

Dr. Darwin has ingeniously explained the production of snow on the tops of the highest mountains, by the precipitation of vapour from the rarefied air which ascends from plains and valleys. "The Andes," says Sir H. Davy, "placed almost under the line, rise in the midst of burning sands; about the middle height is a pleasant and mild climate; the summits are covered with unchanging snows; and these ranges of temperature are always distinct; the hot winds from below, if they ascend, become cooled in consequence of expansion and the cold air; if by any force of the blast it is driven downwards, it is condensed, and rendered warmer as it descends."

Evaporation and rarefaction, the grand means employed by nature to temper the excessive heats of the torrid zone, operate very powerfully among mountains and seas. But the level sands are devoured by unmitigated heat. In milder climates, the fervours of the solstitial sun are assuaged by the vapours copiously raised from every river and field, while the wintry cold is moderated by the condensation of atmospheric vapours in the form of snow.

The equilibrium of animal temperature is maintained, by the copious discharge of vapour from the lungs and the skin. The suppression of this exhalation is a common cause of many formidable diseases. Among these, fever takes the lead. The ardour of the body in this case of suppressed perspiration, sometimes exceeds the standard of health by six or seven degrees. The direct and natural means of allaying this morbid temperature, were first systematically enjoined by Dr. Currie of Liverpool. He showed, that the dashing or affusion of cold water on the skin of a fever patient, has most sanatory effects, when the heat is steadily above 98°, and when there is no sensation of chilliness, and no moisture on the surface. Topical refrigeration is elegantly procured, by applying a piece of muslin or tissue paper to any part of the skin, and moistening it with ether, carburet of sulphur, or alcohol. By pouring a succession of drops of ether, on the surface of a thin glass tube containing water, a cylinder of ice may be formed at midsummer. The most convenient plan which the chemist can employ, to free a gas from vapour, is to pass it slowly through a long tortuous tube wrapt in porous paper wetted with ether.

On the other hand, when he wishes to expose his vessels to a regulated heat, he makes hot vapour be condensed on their cold surface. The heat thus disengaged from the vapour, passes into the vessel, and speedily raises it to a temperature which he can adjust with the nicest precision. A vapour bath ought therefore to be provided for every laboratory. That which I got constructed a few years ago for the Institution, is so simple and efficacious as to merit a description.—A square tin box, about 18 inches long, 12 bread, and 6 deep, has its bottom hollowed a little by the hammer towards its centre, in which a round hole is cut of five or six inches diameter. Into this, a tin tube three or four inches long is soldered. This tube is made to fit tightly into the mouth of a common tea-kettle, which has a folding handle. The top of the box has a number of circular holes cut into it, of different diameters, into which evaporating capsules of platina, glass, or porcelain, are placed. When the kettle, filled with water, and with its nozzle corked, is set on a stove, the vapour, playing on the bottoms of the capsules, heats them to any required temperature; and being itself continually condensed, it runs back into the kettle, to be raised again, in ceaseless cohobation. With a shade above, to screen the vapour chest from soot, the kettle may be placed over a common fire. The orifices not in use, are closed with tin lids. In drying precipitates, I cork up the tube of the glass funnel, and place it, with its filter, directly into the proper sized opening. For drying red cabbage, violet petals, &c. a tin tray is provided, which fits close on the top of the box, within the rim which goes about it. The round orifices are left open when this tray is applied. Such a form of apparatus is well adapted to inspissate the pasty mass, from which lozenges and troches are to be made.

But the most splendid trophy erected to the science of caloric, is the steam-engine of Watt. This illustrious philosopher, from a mistake of his friend Dr. Robison, has been hitherto defrauded of a part of his claims to the admiration and gratitude of mankind. The fundamental researches on the constitution of steam, which formed the solid basis of his gigantic superstructure, though they coincided perfectly with Dr. Black's results, were not drawn from them. In some conversations with which this great ornament and benefactor of his country honoured me a short period before his death, he described, with delightful *naïveté* the simple, but decisive experiments, by which he discovered the latent heat of steam. His means and his leisure not then permitting an expensive and complex apparatus, he used apothecaries' phials. With these, he ascertained the two main facts, first, that a cubic inch of water would form about a cubic foot of ordinary steam, or 1728 inches; and that the condensation of that quantity of steam would heat six cubic inches of water from the atmospheric temperature to the boiling point. Hence he saw that six times the difference of temperature, or fully 900° of heat had been employed in giving elasticity to steam; which must be all abstracted before a complete vacuum could be procured under the piston of the steam-engine. These practical determinations he afterwards found to agree pretty nearly with the observations of Dr. Black. Though Mr. Watt was then known to the Doctor, he was not on those terms of intimacy with him, which he afterwards came to be, nor was he a member of his class.

Mr. Watt's three capital improvements, which seem to have nearly exhausted the resources of science and art, were the following 1. The separate condensing chest, immersed in a body of cold water, and connected merely by a slender pipe with the great cylinder, in which the impelling piston moved. On opening a valve or stop-cock of communication, the elastic steam which had floated the ponderous piston, rushed into the distant chest with magical velocity, leaving an almost perfect vacuum in the cylinder, into which the piston was forced by atmospheric pressure. What had appeared impossible to all previous engineers was thus accomplished. A vacuum was formed without cooling the cylinder itself. Thus it remained boiling hot, ready the next instant to receive and maintain the elastic steam. 2. His second grand improvement consisted in closing the cylinder at top, making the piston rod slide through a stuffing box in the lid, and causing the steam to give the impulsive pressure instead of the atmosphere. Henceforth the waste of heat was greatly diminished. 3. The final improvement was the double impulse, whereby the power of his engines, which was before so great, was in a moment more than doubled. The counterweight required in the single stroke engine, to depress the pump-end of the working beam, was now laid aside. He thus freed the machine from a dead weight or drag of many hundred pounds, which had hung upon it from its birth, about seventy years before.

The application of steam to heat apartments, is another valuable fruit of these studies. Safety, cleanliness, and comfort, thus combine in giving a genial warmth for every purpose of private accommodation, or public manufacture. It has been ascertained, that *one cubic foot* of boiler will heat about *two thousand feet* of space, in a cotton mill, whose average heat is from 70° to 80° Fahr. And if we allow 25 cubic feet of a boiler for a horse's power in a steam-engine supplied by it, such a boiler would be adequate to the warming of fifty thousand cubic feet of space. It has been also ascertained, that one square foot of surface of steam pipe, is adequate to the warming of two hundred cubic feet of space. This quantity is adapted to a well finished ordinary brick or stone building. The safety valve on the boiler should be loaded with 2½ pounds for an area of a square inch, as is the rule for Mr. Watt's engines. Cast iron pipes are preferable to all others, for the diffusion of heat. Freedom of expansion must be allowed, which in cast iron may be taken at about a tenth of an inch for every ten feet in length. The pipes should be distributed within a few inches of the floor.

Steam is now used extensively for drying muslin and calicoes. Large cylinders are filled with it, which, diffusing in the apartment a temperature of 100° or 130°, rapidly dry the suspended cloth. Occasionally the cloth is made to glide in a serpentine manner closely round a series of steam cylinders, arranged in parallel rows. It is thus safely and thoroughly dried in the course of a minute. Experience has shown, that bright dyed yarns like scarlet, dried in a common *stove* heat of 128°, have their colour darkened, and acquire a harsh feel; while similar hanks, laid on a *steam* pipe heated up to 165°, retain the shade and lustre they possessed in the wetted state. The people who work in steam drying-rooms are healthy; those who were formerly employed in the stove-heated apartments, became soon sickly and emaciated. These injurious effects must be ascribed to the action of cast iron at a high temperature on the atmosphere.

The heating by steam of large quantities of water or other liquids, either for baths or manufactures, may be effected in two ways; that is, the steam pipe may be plunged with an open end into the water cistern; or the steam may be diffused around the liquid in the interval between the wooden vessel and an interior metallic case. The second mode is of universal applicability. Since a gallon of water in the form of steam will heat 6 gallons at 50°, up to the boiling point, or 162°; 1 gallon of the former will be adequate to heat 18 gallons of the latter up to 100°, making a liberal allowance for waste in the conducting pipe.

Cooking of food for man and cattle is likewise another useful application of steam; "for," says Dr. Black, "it is the most effectual carrier of heat that can be conceived, and will deposite it only on such bodies as are colder than boiling water." Hence in a range of pots, whenever the first has reached the boiling point, but no sooner, the steam will go onwards to the second, then to the third, and thus in succession. Inspection of the last will therefore satisfy us of the condition of the preceding vessels. Distillation has been lately practised, by surrounding the still with a strong metallic case, and filling the interstice with steam heated up to 260° or 280°. But notwithstanding of safety valves, and every ordinary attention, dangerous explosions have happened. Distillation *in vacuo*, by the heat of external steam of ordinary strength, would be a safe and elegant process. The old, and probably very exact experiments of Mr. Watt on this subject, do not lead us, however, to expect any saving of fuel, merely by the *vacuum* distillation. "The unexpected result of these experiments is, that there is no advantage to be expected in the manufacture of ardent spirits by distillation *in vacuo*. For we find, that the latent heat of the steam is at least as much increased as the sensible heat is diminished."—*Dr. Black's Lectures*, vol. i. p. 190.

By advantage is evidently meant saving of fuel. But in preparing spirits, ethers, vinegars, and essential oils, there would undoubtedly be a great advantage relative to flavour. Every risk of *empyreuma* is removed.

Chambers filled with steam heated to about 125° Fahr. have been introduced with advantage into medicine, under the name of vapour baths. Dry air has also been used. It can be tolerated at a much greater heat than moist air; see TEMPERATURE. A large cradle, containing sawdust heated with steam, should be kept in readiness at the houses erected by the Humane Society, for the recovery of drowned persons; or a steam chamber might be attached to them for this purpose, as well as general medicinal uses.

I have thus completed what I conceive to belong directly to caloric in a chemical dictionary. Under *alcohol, attraction, blow-pipe, climate, combustion, congelation, digester, distillation, electricity, gas, light, pyrometer, thermometer, water*, some interesting correlative facts will be found.

* CALORIMETER. An instrument contrived by Lavoisier and Laplace, to measure the heat given out by a body in cooling, from the quantity of ice it melts. It consists of 3 vessels, one placed within the other, so as to leave 2 cavities between them; and a frame of iron network, to be suspended in the middle of the inner vessel. This network is to hold the heated body. The The two exterior concentric interstices are filled with bruised ice. The outermost serves to screen, from the atmosphere, the ice in the middle space, by the fusion of which the heat given out by the central hot body is measured. The water runs off through the bottom, and terminates in the shape of a funnel, with a stop-cock.*

† CALORIMOTOR. This is an appellation given by me to galvanic instruments, in which the calorific influence or effects are attended by scarcely any electrical power; and especially to apparatus, employed by me, consisting of one or two galvanic pairs of enormous size.

Volta considered all galvanic apparatus as consisting of one or more electromotors, or movers of the electric fluid. To me, it appeared, that they were movers of both heat and electricity; the ratio of the quantity of the latter put in motion, to the quantity of the former put in motion, being as the number of the series to the superficies. Hence the word *electromotor* can only be applicable, when the caloric becomes evanescent, and electricity almost the sole product, as in De Luc's and Zamboni's Columns; and the word *calorimotor* ought to be used, when electricity becomes evanescent, and caloric appears the sole product.

The heat evolved by one galvanic pair has been found by the experiments which I instituted, to increase in quantity, but to diminish in intensity, as the size of the surfaces may be enlarged. A pair containing about fifty square feet of each metal, will not fuse platina, nor deflagrate iron, however small may be the wire employed; for the heat produced in metallic wires is not improved by a reduction in their size beyond a certain point. Yet the metals abovementioned are easily fused or deflagrated by smaller pairs, which would have no perceptible influence on masses that might be sensibly ignited by larger pairs. These characteristics were fully demonstrated, not only by my own apparatus, but by those constructed by Messrs. Wetherill and Peale, and which were larger, but less capable of exciting intense ignition. Mr. Peale's apparatus contained nearly seventy square feet, Mr. Wetherill's nearly one hundred, in the form of concentric coils; yet neither could produce a heat above redness on the smallest wires. At my suggestion, Mr. Peale separated the two surfaces in his coils into four alternating, constituting two galvanic pairs in one recipient. Iron wire was then easily burned and platina fused by it. These facts, together with the incapacity of the calorific fluid extricated by the calorimotor to permeate charcoal, next to metals the best electrical conductor, must sanction the position I assigned to it, as being in the opposite extreme from the columns of De Luc and Zamboni. For as in these, the phenomena are such as are characteristic of pure electricity, so in one very large galvanic pair, they almost exclusively demonstrate the agency of pure caloric.

A plate of a calorimotor will be found at the end of this work, with a description.

When this instrument is lowered into a solution, containing about a seventieth of sulphuric acid, a wire, placed between the poles, becomes white hot, and takes fire, emitting the most brilliant sparks. In the interim, an explosion usually gives notice of the extrication of hydrogen in a quantity adequate to reach the burning wire. Immediately after the explosion, the hydrogen is reproduced with less intermixture of air, and rekindles, corruscating from among the forty interstices, and passing from one side of the machine to the other, in opposite directions and at various times, so that the combinations are innumerable. The flame assumes various hues, from the solution of more or less of the metals, and a froth, apparently on fire, rolls over the sides of the recipient. When the calorimotor is withdrawn from the acid solution, the surface of this fluid for many seconds, presents a sheet of fiery foam.

I ascertained that the galvanic fluid, as extricated by this apparatus, does not permeate charcoal. This demonstrates that it cannot be electricity, as of the latter, charcoal is next to metals the best conductor.

See Memoirs on a New Theory of Galvanism in Silliman's Journal, Annals of Philosophy, and Philosophical Magazine.†

* **Calp.** An argillo-ferruginous limestone.*

* **Cameleon Mineral.** When pure potash and black oxide of manganese are fused together in a crucible, a compound is formed whose solution in water, at first green, passes spontaneously through the whole series of coloured rays to the red. From this latter tint, the solution may be made to retrograde in colour to the original green, by the addition of potash; or it may be rendered altogether colourless, by adding either sulphurous acid or chlorine to the solution, in which case there may or may not be a precipitate, according to circumstances. MM. Chevillot and Edouard have lately read some interesting memoirs on this substance, before the Academy of Sciences. They found, that when potash and the green oxide of manganese were heated in close vessels, containing azote, no cameleon is formed. The same result followed with the brown oxide, and ultimately with the black. They therefore ascribe the phenomena to the absorption of oxygen, which is greatest when the oxide of manganese equals the potash in weight. They regard it as a manganesiate of potash, though they have hitherto failed in their attempts to separate this supposed tetroxide, or manganesic acid. When acids are poured upon the *green* cameleon, or an alkali upon the *red*, they are equally changed from one colour to the other; even boiling and agitation are sufficient to disengage the excess of potash in the green cameleon, and to change it into red. Many acids also, when used in excess, decompose the cameleon entirely, by taking the potash from it, disengaging the oxygen, and precipitating the manganese in the state of black oxide. Sugar, gums, and several other substances, capable of taking away the oxygen, also decompose the cameleon, and an exposure to the air likewise produces the same effect. Soda, barytes, and strontites, also afford peculiar cameleons. The red potash cameleon is perfectly neutral. Phosphorus brought in contact with it produces a detonation; and it sets some other combustibles on fire. Exposed alone to heat, it is resolved into oxygen, black oxide of manganese, and green cameleon, or submanganesiate of potash.*

Campeachy Wood. See **Logwood.**

Camphor. There are two kinds grow in the East, the one produced in the islands of Sumatra and Borneo, and the other produced in Japan and China.

Camphor is extracted from the roots, wood, and leaves of two species of laurus, the roots affording by far the greatest abundance. The method consists in distilling with water in large iron pots, serving as the body of a still, with earthen heads adapted, stuffed with straw, and provided with receivers. Most of the camphor becomes condensed in the solid form among the straw, and part comes over with the water.

The sublimation of camphor is performed in low flat-bottomed glass vessels placed in sand; and the camphor becomes concrete in a pure state against the upper part, whence it is afterwards separated with a knife, after breaking the glass. Lewis asserts that no addition is requisite in the purification of camphor; but that the chief point consists in managing the fire, so that the upper part of the vessel may be hot enough to bake the sublimate together into a kind of cake. Chaptal says, the Hollanders mix an ounce of quicklime with every pound of camphor previous to the distillation.

Purified camphor is a white concrete crystalline substance, not brittle, but easily crumbled, having a peculiar consistence resembling that of spermaceti, but harder. It has a strong lively smell, and an acrid taste; is so volatile as totally to exhale when left exposed in a warm air; is light enough to swim on water; and is very inflammable, burning with a very white flame and smoke, without any residue.

The roots of zedoary, thyme, rosemary, sage, the inula hellenium, the anemony, the pasque flower or pulsatilla, and other vegetables, afford camphor by distillation. It is observable, that all these plants afford a much larger quantity of camphor, when the sap has been suffered to pass to the concrete state by several months' drying. Thyme and peppermint, slowly dried, afford much camphor; and Mr. Achard has observed, that a smell of camphor is disengaged when volatile oil of fennel is treated with acids.

Mr. Kind, a German chemist, endeavouring to incorporate muriatic acid gas with oil of turpentine, by putting this oil into the vessels in which the gas was received when extricated, found the oil change first yellow, then brown, and lastly, to be almost wholly coagulated into a crystalline mass, which comported itself in every respect like camphor. Tromsdorff and Boullay confirm this. A small quantity of camphor may be obtained from oil of turpentine by simple distillation at a very gentle heat. Other essential oils, however, afford more. By evaporation in shallow vessels, at a heat not exceeding 57° F. Mr. Proust obtained from oil of lavender .25, of sage .21, of marjoram .1014, of rosemary .0625. He conducted the operation on a pretty large scale.

Camphor is not soluble in water in any perceptible degree, though it communicates its smell to that fluid, and may be burned as it floats on its surface. It is said, however, that a surgeon at Madrid has effected its solution in water by means of the carbonic acid.

Camphor may be powdered by moistening it with alcohol, and triturating it till dry. It may be formed into an emulsion by previous grinding with near three times its weight of almonds, and afterwards gradually adding the water. Yolk of egg and mucilages are also effectual for this purpose; but sugar does not answer well.

It has been observed by Romieu, that small pieces of camphor floating on water have a rotatory motion.

Alcohol, ethers, and oils, dissolve camphor.

The addition of water to the spirituous or acid solutions of camphor, instantly separates it.

Mr. Hatchett has particularly examined the action of sulphuric acid on camphor. A hundred grains of camphor were digested in an ounce of concentrated sulphuric acid for two days. A gentle heat was then applied, and the digestion continued for two days longer. Six ounces of water were then added, and the whole distilled to dryness. Three grains of an essential oil, having a mixed odour of lavender and peppermint, came over with the water. The residuum being treated twice with two ounces of alcohol each time, fifty-three grains of compact coal in small fragments remained undissolved. The alcohol, being evaporated in a water bath, yielded forty-nine grains of a blackish-brown substance which was bitter, astringent, had the smell of caromel, and formed a dark brown solution with water. This solution threw down very dark brown precipitates, with sulphate of iron, acetate of lead, muriate of tin, and nitrate of lime. It precipitated gold in the metallic state. Isinglass threw down the whole of what was dissolved in a nearly black precipitate.

When nitric acid is distilled repeatedly in large quantities from camphor, it converts it into a peculiar acid. See Acid (Camphoric).

* Camphor melts at 288°, and boils at the temperature of 400°. By passing it in vapour through peroxide of copper, Dr. Thomson converted it into carbonic acid and water. He operated upon a single grain. He infers its composition to be

Carbon,	0.738	8½ at'ms.	= 6.375	73.91
Hydrogen,	0.144	10	= 1.250	14.49
Oxygen,	0.118	1	= 1.000	11.60
	1.000		8.625	100.00

As an internal medicine, camphor has been frequently employed in doses of from 5 to 20 grains, with much advantage; to procure sleep in mania, and to counteract gangrene. Though a manifest stimulant, when externally applied, it appears from the reports of Cullen and others, rather to diminish the animal temperature and the frequency of the pulse. In large doses it acts as a poison, an effect best counteracted by opium. It is administered to alleviate the irritating effects of cantharides, mezereon, the saline preparations of mercury and drastic purgatives. It lessens the nauseating tendency of squill, and prevents it from irritating the bladder. It is employed externally as a discutient.* Dissolved in acetic acid, with some essential oils, it forms the aromatic vinegar, for which we are indebted to the elder Mr. Henry. It remarkably promotes the solution of copal. Its effluvia are very noxious to insects, on which account it is much used to defend subjects of natural history from their ravages.

* **Cancer, Matter of.** This morbid secretion was found by Dr. Crawford to give a green colour to sirup of violets, and

treated with sulphuric, acid, to emit a gas resembling sulphuretted hydrogen, which he supposes to have existed in combination with ammonia in the ulcer. Hence the action of virulent pus on metallic salts. He likewise observed, that its odour was destroyed by aqueous chlorine, which he therefore recommends for washing cancerous sores.*

* **Candles.** Cylinders of tallow or wax, containing in their axis a spongy cord of cotton or hemp. A few years ago I made a set of experiments on the relative intensities of light, and duration of different candles, the result of which is contained in the following table:—

Number in a Pound.	*Duration of a Candle.*	*Weight in grains.*	*Consumption per hour, grains.*	*Proportion of Light.*	*Economy of Light.*	*Candles equal one argand.*
10 mould.	5 h. 9 m.	682	132	12¼	68	5.7
10 dipped.	4 36	672	150	13	65½	5.25
8 mould.	6 31	856	132	10½	59½	6.6
6 do.	7 2½	1160	163	14⅔	66	5.0
4 do.	9 36	1787	186	20¼	80	3.5
Argand oil flame.			512	69.4	100	

A Scotch mutchkin, or 1-8th of a gallon of good seal oil, weighs 6010 gr. or 13 and 1-10th oz. avoirdupois, and lasts in a bright argand lamp, 11 hours 44 min. The weight of oil it consumes per hour, is equal to four times the weight of tallow in candles, 8 to the pound, and 3 1-7th times the weight of tallow in candles, 6 to the pound. But its light, being equal to that of 5 of the latter candles, it appears from the above table, that 2 pounds weight of oil, value 1*s.* in an argand, are equivalent in illuminating power to 3 pounds of tallow candles, which cost about three shillings. The larger the flame in the above candles, the greater the economy of light.*

* **Cannel Coal.** See Coal.*

* **Cannon Metal.** See Copper.*

* **Cantharides.** Insects vulgarly called Spanish flies: lytta vesicatoria is the name adopted from Gmelin, by the London college. This insect is two-thirds of an inch in length, one-fourth in breadth, oblong, and of a gold shining colour, with soft elytera or wing sheathes, marked with three longitudinal raised stripes, and covering brown membranous wings. An insect of a square form, with black feet, but possessed of no vesicating property, is sometimes mixed with the cantharides. They have a heavy disagreeable odour, and acrid taste.

If the inspissated watery decoction of these insects be treated with pure alcohol, a solution of a resinous matter is obtained, which being separated by gentle evaporation to dryness, and submitted for some time to the action of sulphuric ether, forms a yellow solution. By spontaneous evaporation crystalline plates are deposited, which may be freed from some adhering colouring matter by alcohol. Their appearance is like spermaceti. They are soluble in boiling alcohol, but precipitate as it cools. They do not dissolve in water. According to M. Robiquet, who first discovered them, these plates form the true blistering principle. They might be called Vesicatorin. Besides the above peculiar body, cantharides contain, according to M. Robiquet, a green bland oil, insoluble in water, soluble in alcohol; a black matter, soluble in water, insoluble in alcohol, without blistering properties; a yellow viscid matter, mild, soluble in water and alcohol; the crystalline plates; a fatty bland matter; phosphates of lime and magnesia; a little acetic acid, and much lithic or uric acid. The blistering fly taken into the stomach in doses of a few grains, acts as a poison, occasioning horrible satyriasis, delirium, convulsions, and death. Some frightful cases are related by Orfila, vol. i. part 2d. Oils, milk, sirups, frictions on the spine, with volatile liniment and laudanum, and draughts containing musk, opium, and camphorated emulsion, are the best antidotes.*

Caoutchouc. This substance, which has been improperly termed *elastic gum*, and vulgarly, from its common application to rub out pencil marks on paper, *India rubber*, is obtained from the milky juice of different plants in hot countries. The chief of these are the *Jatropha elastica*, and *Urceola elastica*.

The juice is applied in successive coatings on a mould of clay, and dried by the fire or in the sun; and when of a sufficient thickness, the mould is crushed, and the pieces shaken out. Acids separate the caoutchouc from the thinner part of the juice at once by coagulating it. The juice of old plants yields nearly two-thirds of its weight; that of younger plants less. Its colour, when fresh, is yellowish white, but it grows darker by exposure to the air.

The elasticity of this substance is its

most remarkable property: when warmed, as by immersion in hot water, slips of it may be drawn out to seven or eight times their original length, and will return to their former dimensions nearly. Cold renders it stiff and rigid, but warmth restores its original elasticity. Exposed to the fire it softens, swells up, and burns with a bright flame. In Cayenne it is used to give light as a candle. Its solvents are ether, volatile oils, and petroleum. The ether, however, requires to be washed with water repeatedly, and in this state it dissolves it completely. Pelletier recommends to boil the caoutchouc in water for an hour; then to cut it into slender threads; to boil it again about an hour; and then to put it into rectified sulphuric ether in a vessel close stopped. In this way he says it will be totally dissolved in a few days, without heat, except the impurities, which will fall to the bottom, if ether enough be employed. Berniard says, the nitrous ether dissolves it better than the sulphuric. If this solution be spread on any substance, the ether evaporates very quickly, and leaves a coating of caoutchouc unaltered in its properties. Naphtha, or petroleum, rectified into a colourless liquid, dissolves it, and likewise leaves it unchanged by evaporation. Oil of turpentine softens it, and forms a pasty mass, that may be spread as a varnish, but is very long in drying. A solution of caoutchouc in five times its weight of oil of turpentine, and this solution dissolved in eight times its weight of drying linseed oil by boiling, is said to form the varnish of air-balloons. Alkalis act upon it so as in time to destroy its elasticity. Sulphuric acid is decomposed by it; sulphurous acid being evolved, and the caoutchouc converted into charcoal. Nitric acid acts upon it with heat; nitrous gas being given out, and oxalic acid crystallizing from the residuum. On distillation it gives out ammonia, and carburetted hydrogen.

Caoutchouc may be formed into various articles without undergoing the process of solution. If it be cut into a uniform slip of a proper thickness, and wound spirally round a glass or metal rod, so that the edges shall be in close contact, and in this state be boiled for some time, the edges will adhere so as to form a tube. Pieces of it may be readily joined by touching the edges with the solution in ether: but this is not absolutely necessary, for, if they be merely softened by heat, and then pressed together, they will unite very firmly.

If linseed oil be rendered very drying by digesting it upon an oxide of lead, and afterwards applied with a small brush on any surface, and dried by the sun or in the smoke, it will afford a pellicle of considerable firmness, transparent, burning like caoutchouc, and wonderfully elastic. A pound of this oil, spread upon a stone, and exposed to the air for six or seven months, acquired almost all the properties of caoutchouc: it was used to make catheters and bougies, to varnish balloons, and for other purposes.

Of the mineral caoutchouc there are several varieties: 1. Of a blackish-brown inclining to olive, soft, exceedingly compressible, unctuous, with a slightly aromatic smell. It burns with a bright flame, leaving a black oily residuum, which does not become dry. 2. Black, dry, and cracked on the surface, but, when cut into, of a yellowish-white. A fluid resembling pyrolignic acid exudes from it when recently cut. It is pellucid on the edges, and nearly of a hyacinthine red colour. 3. Similar to the preceding, but of a somewhat firmer texture, and ligneous appearance, from having acquired consistency in repeated layers. 4. Resembling the first variety, but of a darker colour, and adhering to gray calcareous spar, with some grains of galæna. 5. Of a liver-brown colour, having the aspect of the vegetable caoutchouc, but passing by gradual transition into a brittle bitumen, of vitreous lustre, and a yellowish colour. 6. Dull reddish-brown, of a spongy or cork-like texture, containing blackish-gray nuclei of impure caoutchouc. Many more varieties are enumerated.

One specimen of this caoutchouc has been found in a petrified marine shell enclosed in a rock, and another enclosed in crystallized fluor spar.

The mineral caoutchouc resists the action of solvents still more than the vegetable. The rectified oil of petroleum affects it most, particularly when by partial burning it is resolved into a pitchy viscous substance. A hundred grains of a specimen analyzed in the dry way by Klaproth, afforded carburetted hydrogen gas 38 cubic inches, carbonic acid gas 4, bituminous oil 73 grains, acidulous phlegm 1.5, charcoal 6.25, lime 2, silex 1.5, oxide of iron .75, sulphate of lime .5, alumina .25.

Carat. See Assay.

Carbon. When vegetable matter, particularly the more solid, as wood, is exposed to heat in close vessels, the volatile parts fly off, and leave behind a black porous substance, which is charcoal. If this be suffered to undergo combustion in contact with oxygen, or with atmospheric air, much the greater part of it will combine with the oxygen, and escape in the form of gas; leaving about a two-hundredth part, which consists chiefly of different saline and metallic substances. This pure inflammable part of the charcoal is what is commonly called *carbon;* and if the gas be received into proper vessels, the carbon will be found to have been converted by the oxygen into an acid, called the carbonic. See Acid (Carbonic).

From the circumstance, that inflammable substances refract light, in a ratio greater than that of their densities, Newton inferred, that the diamond was inflammable. The quantity of the inflammable part of charcoal requisite to form a hundred parts of carbonic acid, was calculated by Lavoisier to be twenty-eight parts. From a careful experiment of Mr. Tennant, 27.6 parts of diamond, and 72.4 of oxygen, formed 100 of carbonic acid; and hence he inferred the identity of the diamond, and the inflammable part of charcoal.

* Diamonds had been frequently consumed in the open air with burning glasses; but Lavoisier first consumed them in oxygen gas, and discovered carbonic acid to be the only result. Sir George Mackenzie showed, that a red heat, inferior to what melts silver, is sufficient to burn diamonds. They first enlarge somewhat in volume, and then waste with a feeble flame. M. Guyton Morveau was the first who dropped diamonds into melted nitre, and observed the formation of carbonic acid.

From a number of experiments M. Biot has made on the refraction of different substances, he has been led to form a different opinion. According to him, if the elements of which a substance is composed be known, their proportions may be calculated with the greatest accuracy from their refractive powers. Thus he finds, that the diamond cannot be pure carbon, but requires at least one-fourth of hydrogen, which has the greatest refractive power of any substance, to make its refraction commensurate to its density.

In 1809, Messrs. Allen and Pepys made some accurate researches on the combustion of various species of carbon in oxygen, by means of an elegant apparatus of their own contrivance. A platina tube traversing a furnace, and containing a given weight of the carbonaceous substance, was connected at the ends with two mercurial gasometers, one of which was filled with oxygen gas, and the other was empty. The same weight of diamond, carbon, and plumbago, yielded very nearly the same volume of carbonic acid. Sir H. Davy was the first to show that the diamond was capable of supporting its own combustion in oxygen, without the continued application of extraneous heat, and he thus obviated one of the apparent anomalies of this body, compared with charcoal. This phenomenon, by his method, can now be easily exhibited. If the diamond, supported in a perforated cup, be fixed at the end of a jet, so that a stream of hydrogen can be thrown on it, it is easy, by inflaming the jet, to ignite the gem, and whilst in that state to introduce it into a globe or flask containing oxygen. On turning off the hydrogen, the diamond enters into combustion, and will go on burning till nearly consumed. The loss of weight, and corresponding production of carbonic acid, were thus beautifully shown. A neat form of apparatus for this purpose is delineated by Mr. Faraday, in the 9th volume of the Journal of Science. Sir. H. Davy found, that diamonds gave a volume of pure carbonic acid, equal to the oxygen consumed; charcoal and plumbago afforded a minute portion of hydrogen.* See Diamond.

Well-burned charcoal is a conductor of electricity, though wood simply deprived of its moisture by baking is a non-conductor; but it is a very bad conductor of caloric, a property of considerable use on many occasions, as in lining crucibles.

It is insoluble in water, and hence the utility of charring the surface of wood exposed to that liquid, in order to preserve it, a circumstance not unknown to the ancients. This preparation of timber has been proposed as an effectual preventive of what is commonly called the dry rot. It has an attraction, however, for a certain portion of water, which it retains very forcibly. Heated red-hot, or nearly so, it decomposes water; forming with its oxygen, carbonic acid, or carbonic oxide, according to the quantity present; and with the hydrogen a gaseous carburet, called carburetted hydrogen; or heavy inflammable air.

Charcoal is infusible by any heat. If exposed to a very high temperature in close vessels it loses little or nothing of its weight, but shrinks, becomes more compact, and acquires a deeper black colour.

Recently prepared charcoal has a remarkable property of absorbing different gases, and condensing them in its pores, without any alteration of their properties or its own.

* The following are the latest results of M. Theodore de Saussure, with boxwood charcoal, the most powerful species:

Gaseous ammonia, -	90 vols.
Ditto muriatic acid,	85
Ditto sulphurous acid,	65
Sulphuretted hydrogen,	55
Nitrous oxide, - -	40
Carbonic oxide, -	35
Olefiant gas, - - -	35
Carbonic oxide, -	9.42
Oxygen, - - -	9.25
Azote, - - -	7.5
Light gas from moist charcoal,	5.0
Hydrogen, - - -	1.75

Very light charcoal, such as that of cork, absorbs scarcely any air; while the pit-coal of Rastiberg, sp. gr. 1.326, absorbs 10½ times its volume. The absorption was always completed in 24 hours. This curious faculty, which is common to all porous bodies, resembles the action of capillary tubes on liquids. When a piece of charcoal, charged with one gas, is transferred into another, it absorbs some of it, and parts with a portion of that first condensed. In the experiments of Messrs. Allen and Pepys, charcoal was found to imbibe from the atmosphere in a day about 1-8th of its weight of water. For a general view of absorption, see GAS.

When oxygen is condensed by charcoal, carbonic acid is observed to form at the end of several months. But the most remarkable property displayed by charcoals impregnated with gas, is that with sulphuretted hydrogen, when exposed to the air or oxygen gas. The sulphuretted hydrogen is speedily destroyed, and water and sulphur result, with the disengagement of considerable heat. Hydrogen alone has no such effects. When charcoal was exposed by Sir H. Davy to intense ignition *in vacuo*, and in condensed azote, by means of Mr. Children's magnificent voltaic battery, it slowly volatilized, and gave out a little hydrogen. The remaining part was always much harder than before; and in one case so hard as to scratch glass, while its lustre was increased. This fine experiment may be regarded as a near approach to the production of diamond.*

Charcoal has a powerful affinity for oxygen, whence its use in disoxygenating metallic oxides, and restoring their base to its original metallic state, or reviving the metal. Thus too it decomposes several of the acids, as the phosphoric and sulphuric, from which it abstracts their oxygen, and leaves the phosphorus and sulphur free.

Carbon is capable of combining with sulphur, and with hydrogen. With iron it forms steel; and it unites with copper into a carburet, as observed by Dr. Priestley.

A singular and important property of charcoal is that of destroying the smell, colour, and taste of various substances: for the first accurate experiments on which we are chiefly indebted to Mr. Lowitz of Petersburgh, though it had been long before recommended to correct the fœtor of foul ulcers, and as an antiseptic. On this account it is certainly the best dentifrice. Water that has become putrid by long keeping in wooden casks, is rendered sweet by filtering through charcoal powder, or by agitation with it; particularly if a few drops of sulphuric acid be added. Common vinegar boiled with charcoal powder becomes perfectly limpid. Saline solutions, that are tinged yellow or brown, are rendered colourless in the same way, so as to afford perfectly white crystals. The impure carbonate of ammonia obtained from bones, is deprived both of its colour and fetid smell by sublimation with an equal weight of charcoal powder. Malt spirit is freed from its disagreeable flavour by distillation from charcoal; but if too much be used, part of the spirit is decomposed. Simple maceration, for eight or ten days, in the proportion of about 1-150th of the weight of the spirit, improves the flavour much. It is necessary, that the charcoal be well burned, brought to a red heat before it is used, and used as soon as may be, or at least be carefully excluded from the air. The proper proportion too should be ascertained by experiment on a small scale, The charcoal may be used repeatedly, by exposing it for some time to a red heat before it is again employed.

Charcoal is used on particular occasions as fuel, on account of its giving a strong and steady heat without smoke. It is employed to convert iron into steel by cementation. It enters into the composition of gunpowder. In its finer states, as in ivory black, lampblack, &c. it forms the basis of black paints, Indian ink, and printers' ink.

* The purest carbon for chemical purposes is obtained by strongly igniting lampblack in a covered crucible. This yields, like the diamond, unmixed carbonic acid by combustion in oxygen.

Carbon unites with all the common simple combustibles, and with azote, forming a series of most important compounds. With sulphur it forms a curious limpid liquid called carburet of sulphur, or sulphuret of carbon. With phosphorus it forms a species of compound, whose properties are imperfectly ascertained. It unites with hydrogen in two definite proportions, constituting sub-carburetted and carburetted hydrogen gases. With azote it forms prussic gas, the cyanogen of M. Gay-Lussac. Steel and plumbago are two different compounds of carbon with iron. In black chalk we find this combustible intimately associated with silica and alumina. The primitive combining proportion, or prime equivalent of carbon, is 0.75 on the oxygen scale.*

* **CARBON (MINERAL)**, is of a grayish-black colour. It is charcoal, with various proportions of earth and iron, without bitumen. It has a silky lustre, and the fibrous texture of wood. It is found in small quantities, stratified with brown coal, slate coal, and pitch coal.*

* **CARBONATES.** Compounds of carbonic acid with the salifiable bases. They are composed either of one prime of the acid and one of the base, or of two of the acid and one of the base. The former set of compounds is called carbonates, the latter bicarbonates. See CARBONIC ACID.

As the system of chemical equivalents, or atomic theory of chemical combination, derives some of its fundamental or prime proportions from the constitution of the carbonates, their analysis requires peculiar precautions. In the Annals of Philosophy for October 1817, I gave a description of a new instrument for accomplishing this purpose with the minutest precision.

The usual mode of analysis is to put a given weight of the carbonate in a phial, and add to it a certain quantity of a liquid acid which will dissolve the base, and disengage the carbonic acid. I found, with every care I could take in this method, that variable and uncertain quantities of the liquid acid were apt to be carried off in vapour with the carbonic gas, while a portion of this gaseous acid was generally retained in the saline liquid. Hence, in the analysis of crystallized carbonate of lime, the most uniform of all compounds, we have the following discordant results, which are of importance in the doctrine of equivalents:—

Mr. Kirwan makes it consist of

	45 acid	+ 55 lime.
MM. Aiken,	44	+ 56
Dr. Marcet,	43.9	+ 56.1
Dr. Wollaston,	43.7	+ 56.3
M. Vauquelin,	43.5	+ 56.5
M. Thenard,	43.28	+ 56.72
Dr. Thomson,	43.137	+ 56.863

If we deduce the equivalent of lime from the analysis of Dr. Marcet, so well known for his philosophical accuracy we shall have

Lime = 35.1 to carb. acid 27.5
Dr. Thomson's is 36.25 to do. 27.5

I adduced the following experiment, selected from among many others, as capable of throwing light on the cause of these variations: "Into a small pear-shaped vessel of glass, with a long neck, and furnished with a hollow spherical stopper, drawn out, above and below, into a tube almost capillary, some dilute muriatic acid was put. The whole being poised in a delicate balance, 100 grains of calc spar in rhomboidal fragments were introduced, and the stopper was quickly inserted. A little while after the solution was completed, the diminution of weight, indicating the loss of carbonic acid, was found to be 42.2 grains. Withdrawing the stopper, inclining the vessel to one side for a few minutes, to allow the dense gas to flow out, the diminution became 43.3. Finally, on heating the body of the vessel to about 70°, while the hollow stopper was kept cool, small bubbles of gas escaped from the liquid, and the loss of weight was found to be 43.65, at which point it was stationary. This is a tedious process." The instrument which I subsequently employed is quick in its operation, and still more accurate in its results. It consists of a glass tube of the same strength and diameter with that usually employed for barometers, having a strong egg-shaped bulb, about 2 inches long, and 1¼ wide, blown at one of its ends, while the other is open and recurved like a syphon. The straight part of the tube, between the ball and bend, is about 7 inches long. The capacity, exclusive of the curved part, is a little more than 5 cubic inches. It is accurately graduated into cubic inches and hundredth parts, by the successive additions of equal weights of quicksilver, from a *measure* thermometric tube. Seven troy ounces and 66 grains of quicksilver occupy the bulk of one cubic inch. Four and a half such portions being introduced, will fill the ball, and the beginning of the stem. The point in the tube, which is a tangent to the surface of the mercury, is marked with a file or a diamond. Then 34¼ grains, equal in volume to 1-100th of a cubic inch, being drawn up into the thermometric tube, rest at a certain height, which is also marked. The same measure of mercury is successively introduced and marked off, till the tube is filled.

"In the instrument thus finished, 1-200th of a cubic inch occupies on the stem about 1-14th of an inch, a space very distinguishable. The weight of carbonic acid, equivalent to that number, is less than 1-400th of a grain. The mode of using it is perfectly simple and commodious, and the analytical result is commonly obtained in a few minutes."

For example, five grains of calcareous spar in three or four rhomboids were weighed with great care in a balance by Crighton, which turns with $\frac{1}{400000}$ of the weight in the scales. These are introduced into the empty tube, and made to slide gently along into the spheroid. The instrument is then held in nearly a horizontal position with the left hand, the top of the spheroid resting against the breast, with a small funnel bent at its point, inserted into the orifice of the tube. Quicksilver is now poured in till it be filled, which in this position is accomplished in a few seconds. Should any particles of air be entangled among the mercury, they are discharged by inverting the instrument, having closed the orifice with the finger. On reverting it, and tapping the ball with the finger, the fragments of spar rise to the top. Three or four hundredth parts of a cubic inch of mercury being displaced from the mouth of the tube, that bulk of dilute muriatic acid is poured in; then pressing the forefinger on the orifice, and inclining the instrument forwards, the acid is made to rise through the quicksilver. This, as it is displaced by the cooled carbonic acid, falls into a stone-ware or glass basin, within which the instrument stands in a wooden frame. When the solution is completed, the apparent volume of gas is noted, the mercury in the two legs of the syphon is brought to a level, or the difference of height above the mercury in the basin is observed, as also the temperature of the apartment, and the height of the barometer. Then the ordinary corrections being made, we have the exact volume of carbonic acid contained in five grains of calc spar. In very numerous experiments, which I have made in very different circumstances of atmospherical pressure and temperature, the results have not varied one-hundredth of a cubic inch, on five grains, care being had to screen the instrument from the radiation of the sun or a fire.

As there is absolutely no action exercised on mercury by dilute muriatic acid at ordinary temperatures; as no perceptible difference is made in the bulk of air, by introducing to it over the mercury a little of the acid by itself; and as we can expel every atom of carbonic acid from the muriate of lime, or other saline solution, by gently heating that point of the tube which contains it, it is evident that the total volume of gaseous product must be accurately determined. When a series of experiments is to be performed in a short space of time, I wash the quicksilver with water, dry it with a sponge first, and then with warm muslin. The tube is also washed out and drained. According to my experiments with the above instrument, 5 grains of calcareous spar yield, 4.7 cubic inches of carbonic acid, equivalent to 43.616 per cent. The difference between this number and Dr. Wollaston's is inconsiderable.

Among other results which I obtained from the use of the above instrument, it enabled me to ascertain the true composition of the sublimed carbonate of ammonia, which chemists had previously mistaken. I showed in the Annals of Philosophy for September 1817, that this salt contained 54.5 of carbonic acid, 30.5 ammonia, and 15 water, in 100 parts; numbers which, being translated into the language of equivalents, approach to the following proportions:—

Carbonic acid,	3 primes,	8.25	55.89
Ammonia,	2	4.26	28.86
Water,	2	2.25	15.25
		14.76	100.00

As this volatile salt possesses the curious property of passing readily from one system of definite proportions to another, absolute accordance between experiment and theory cannot be expected. The other salt gave for its constituents, 54.5 carbonic acid + 22.8 ammonia + 22.75 water = 100. Now, if these numbers be referred to Dr. Wollaston's oxygen scale, we shall have,—

			Theory.	*Expt.*
2	primes carbonic acid,	5.50	55.66	54.50
1	ammonia	2.13	21.56	22.80
2	water,	2.25	22.78	22.75

These near approximations to the equivalent ratios in compounds of a variable nature, do not seem to have attracted notice at the time. Dr. Thomson describes in his System the solid subcarbonate found in the shops as indefinite in the proportion of its constituents. In the 14th Number of the Journal of Science, his friend, Mr. Phillips, whose attention to minute accuracy is well known, has published an ingenious paper on the subject, which begins with the following handsome acknowledgment of my labours: "During some late researches, my attention being directed to the composition of the carbonates of ammonia, I began, and had nearly completed an examination of them, before I observed that they had been recently analyzed by Dr. Ure; and I consider his results to be so nearly accurate, that I should have suppressed mine, if I had not noticed some circumstances respecting the compounds in question, which have, I believe, hitherto escaped observation."

Mr. Phillips's communication is valuable. It presents a luminous systematic view of the carbonates of ammonia and soda. Dr. Thomson, in his Annals for July 1820, enumerates that account of the carbonates of ammonia among the improvements made in 1819, without any allusion to my experiments on the ammoniacal salts, published in his own Magazine, nearly three years before he printed his retrospect.

The indications of the above analytical instrument are so minute, as to enable us, by the help of the old and well known theorem for computing the proportions of two metals from the specific gravity of an alloy, to deduce the proportions of the bases from the volume of gas disengaged by a given weight of a mixed carbonate. A chemical problem of this nature was practically solved by me, in presence of two distinguished Professors of the University of Dublin, in May 1816. But such an application is more curious than useful, since a slight variation in the quantity of gas, as well as accidental admixtures of other substances, are apt to occasion considerable errors. It determines, however, the nature and value of a limestone with sufficient practical precision. As 100 grains of magnesian limestone yield 99 cubic inches of gas, a convenient rule for *it* is formed when we say, that 10 grains will yield 10 cubic inches. In the same way marls and common limestones may be examined, by subjecting a certain number of grains, in a graduated syphon tube, to the action of a little muriatic acid over mercury. *From the bulk of evolved gas, expressed in cubic inches and tenths, deduct 1-20th, the remainder will express the proportion of real limestone present in the grains employed.**

* **Carbonate of Barytes.** See **Witherite.***

* **Carbonate of Lime.** See **Calcareous Spar.***

* **Carbonate of Strontian.** See **Strontian** and **Heavy Spar.***

* **Carbonic Acid.** See **Acid Carbonic.***

* **Carbonic Oxide.** A gaseous compound of one prime equivalent of carbon, and one of oxygen, consisting by weight of 0.75 of the former, and 1.00 of the latter. Hence the prime of the compound is 1.75, the same as that of azote. This gas cannot be formed by the chemist by the direct combination of its constituents; for at the temperature requisite for effecting a union, the carbon attracts its full dose of oxygen, and thus generates carbonic acid. It may be procured by exposing charcoal to a long continued heat. The last products consist chiefly of carbonic oxide.

To obtain it pure, however, our only plan is to abstract one proportion of oxygen from carbonic acid, either in its gaseous state, or as condensed in the carbonates. Thus by introducing well calcined charcoal into a tube traversing a furnace, as is represented plate I. fig. 2.; and when it is heated to redness, passing over it backwards and forwards, by means of two attached mercurial gasometers or bladders, a slow current of carbonic acid, we convert the acid into an oxide more bulky than itself. Each prime of the carbon becomes now associated with only one of oxygen, instead of two, as before. The carbon acting here, by its superior mass, is enabled to effect the thorough saturation of the oxygen.

If we subject to a strong heat, in a gun barrel or retort, a mixture of any dry earthy carbonate, such as chalk, or carbonate of strontites, with metallic filings or charcoal, the combined acid is resolved as before into the gaseous oxide of carbon. The most convenient mixture is equal parts of dried chalk and iron, or zinc filings. By passing a numerous succession of electric explosions through one volume of carbonic acid, confined over mercury, two volumes of carbonic oxide, and one of oxygen, are formed, according to Sir H. Davy.

The specific gravity of this gas is stated by Gay-Lussac and Thenard, from theoretical considerations, to be 0.96782, though Mr. Cruickshank's experimental estimate was 0.9569. As the gas is formed by withdrawing from a volume of carbonic acid half a volume of oxygen, while the bulk of the gas remains unchanged, we obtain its specific gravity by subtracting from that of carbonic acid half the specific gravity of oxygen. Hence $1.5277 - 0.5555 = 0.9722$, differing slightly from the above, in consequence of the French chemists rating the specific gravity of the two original gases at 1.51961 and 1.10359. Hence 100 cubic inches weigh $29\frac{2}{3}$ grains at mean pressure and temperature.

This gas burns with a dark-blue flame. Sir H. Davy has shown, that though carbonic oxide in its combustion produces less heat than other inflammable gases, it may be kindled at a much lower temperature. It inflames in the atmosphere, when brought into contact with an iron wire heated to dull redness, whereas carburetted hydrogen is not inflammable by a similar wire, unless it is heated to whiteness, so as to burn with sparks. It requires, for its combustion, half its volume of oxygen gas, producing one volume of carbonic acid. It is not decomposable by any of the simple combustibles, except potassium and sodium. When potassium is heated in a portion of the gas, potash is formed with the precipitation of charcoal, and the disengagement of heat and light. Perhaps iron, at a high temperature, would condense the oxygen and carbon by its strong affinity for these substances. Water condenses $\frac{1}{50}$ of its bulk of the gas. The above processes are those usually prescribed in our systematic works, for procuring the oxide of carbon. In some of them, a portion of carbonic acid is evolved, which may be withdrawn by washing the gaseous product with weak solution of potash, or milk of lime. We avoid the chance of this impurity by extricating the gas from a mixture of dry carbonate of barytes and iron filings, or of oxide of zinc, and previously calcined charcoal. The gaseous product, from the first mixture, is pure oxide of carbon. Oxide of iron, and pure barytes, remain in the retort. Carbonic oxide, when respired, is fatal to animal life. Sir H. Davy took three inspirations of it, mixed with about one-fourth of common air; the effect was a temporary loss of sensation, which was succeeded by giddiness, sickness, acute pains in different parts of the body, and extreme debility. Some days elapsed before he entirely recovered. Since then, Mr. Witter of Dublin was struck down in an apoplectic condition, by breathing this gas; but he was speedily restored, by the inhalation of oxygen. See an interesting account of this experiment, by Mr. Witter, in the Phil. Mag. vol. 43.

When a mixture of it and chlorine is exposed to sunshine, a curious compound, discovered by Dr. John Davy, is formed, to which he gave the name of phosgene gas. I shall describe its properties in treating of chlorine. It has been called chlorocarbonic acid, though chlorocarbonous acid seems a more appropriate name.*

* **Carbuncle**, a gem highly prized by the ancients, probably the *alamandine*, a variety of noble Garnet.*

*CARBURET OF SULPHUR. Called also sulphuret of carbon, and alcohol of sulphur.

This interesting liquid was originally obtained by Lampadius in distilling a mixture of pulverized pyrites and charcoal in an earthen retort, and was considered by him as a peculiar compound of sulphur and hydrogen. But MM. Clement and Desormes, with the precision and ingenuity which distinguish all their researches, first ascertained its true constitution to be carburetted sulphur; and they invented a process of great simplicity, for at once preparing it, and proving its nature. Thoroughly calcined charcoal is to be put into a porcelain tube, that traverses a furnace, at a slight angle of inclination. To the higher end of the tube, a retort of glass, containing sulphur, is luted; and to the lower end is attached an adopter tube, which enters into a bottle with two tubulures, half full of water, and surrounded with very cold water or ice. From the other aperture of the bottle, a bent tube proceeds into the pneumatic trough. When the porcelain tube is brought into a state of ignition, heat is applied to the sulphur, which subliming into the tube, combines with the charcoal, forming the liquid carburet. The conclusive demonstration of such an experiment was however questioned by M. Berthollet, jun. and Cluzel. But MM. Berthollet, Thenard and Vauquelin, the reporters on M. Cluzel's memoir, having made some experiments of their own upon the subject, concluded that the liquid in question was a compound of sulphur and carbon only.

Finally, an excellent paper was written on the carburet by M. Berzelius and Dr. Marcet, who confirmed the results of MM. Clement and Desormes, and added likewise several important facts.

If about ten parts of well calcined charcoal in powder, mixed with fifty parts of pulverized native pyrites (bisulphuret of iron), be distilled from an earthen retort, into a tubulated receiver surrounded with ice, more than one part of sulphuret of carbon may be obtained. If we employ the elegant process of M. Clement, we must take care that the charcoal be perfectly calcined, otherwise no carburet will be obtained. In their early experiments, they attached to the higher end of the porcelain tube a glass one, containing the sulphur in small pieces, and pushed these successively forwards by a wire passing air-tight through a cork, at the upper end of the tube.

Besides the liquid carburet, there is formed some carburetted and sulphuretted hydrogen, and a reddish-brown solid and very combustible matter, which seems to be sulphur slightly carburetted. This substance remains almost entirely in the adopter tube. The liquid carburet occupies the bottom of the receiver bottle, and may be separated from the supernatant water, by putting the whole into a funnel, whose tube is closed with the finger, and letting the denser brown carburet flow out below, whenever the distinction of the liquid into two strata is complete. Thus obtained, the carburet is always yellowish, containing a small excess of sulphur, which may be removed by distillation from a glass retort, plunged in water, at a temperature of 115°. It is now transparent and colourless, of a penetrating, fetid smell, and an acrid burning taste. Its specific gravity varies from 1.263 to 1.272. According to Dr. Marcet, it boils below 110°; according to M. Thenard at 113° F.; and the tension of its vapour at 72.5° is equivalent to a column of 12.53 inches of mercury. At 53.5°, according to Marcet and Berzelius, the tension is equivalent to a column of 7.4 inches, or one-fourth of the mean atmospheric pressure; hence one-third is added to the bulk of any portion of air, with which the liquid may be mixed. A spirit of wine thermometer, having its bulb surrounded with cotton cloth or lint, if dipped in sulphuret of carbon, and suspended in the air, sinks from 60° to 0°. If it be put into the receiver of an air pump, and a moderate exhaustion be made, it sinks rapidly from 60° to — 81°. If a tube containing mercury be treated in the same way, the mercury may be readily frozen even in summer. The drier the air in the receiver, the more easily is the cold produced. Hence the presence of sulphuric acid may be of some service in removing the vapour from the air in the receiver.

This carburet may be cooled to — 80° without congealing; a conclusive proof that combination changes completely the constitution of bodies, since two substances usually solid, form a fluid which we cannot solidify. When a lighted body approaches the surface of the carburet, it immediately catches fire, and burns with a blue sulphurous flame. Carbonic and sulphurous acids are exhaled, and a little sulphur is deposited. A heat of about 700° inflames the vapour of the carburet. Oxygen dilated by it over mercury explodes by the electric spark, with a violent detonation. My eudiometer is peculiarly adapted to the exhibition of this experiment. A portion of oxygen being introduced into the sealed leg, we pour a few drops of the carburet on the surface of the mercury in the open leg, and closing this with the finger, transfer the liquid to the other by a momentary inclination of the syphon. The expansion of volume can be now most accurately measured by bringing the mercury to a level in each leg.

The subsequent explosion occasions no

danger, and a scarcely audible report. The result is a true analysis, if we have mixed oxygen saturated with the vapour at ordinary pressure and temperature, with about its volume of pure oxygen. Otherwise, all the sulphur would not be oxygenated. We obtain, then, sulphurous and carbonic acids, with the excess of oxygen.

The carburet of sulphur dissolves camphor. It does not unite with water; but very readily with alcohol and ether. With chloride of azote it forms a non-detonating compound. The waters of potash, barytes, and lime, slowly decompose it, with the evolution of carbonic acid gas. It combines with ammonia and lime, forming carbo-sulphurets. The carburet, saturated with ammoniacal gas, forms a yellow pulverulent substance, which sublimes unaltered in close vessels, but is so deliquescent that it cannot be passed from one vessel to another without absorbing moisture. When heated in that state, crystals of hydrosulphuret of ammonia form. The compound with lime is made by heating some quicklime in a tube, and causing the vapour of carburet to pass through it. The lime becomes incandescent at the instant of combination.

When the carburet is left for some weeks in contact with nitro-muriatic acid, it is converted into a substance having very much the appearance and physical properties of camphor; being soluble in alcohol and oils, and insoluble in water. This substance is, according to Berzelius, a triple acid, composed of two atoms of muriatic acid, one atom of sulphurous acid, and one atom of carbonic acid. He calls it, muriatico-sulphurous-carbonic acid.

When potassium is heated in the vapour of the carburet, it burns with a reddish flame, and a black film appears on the surface. On admitting water, a greenish solution of sulphuret of potash is obtained, containing a mixture of charcoal. From its vapour passing through ignited muriate of silver, without occasioning any reduction of the metal, it is demonstrated that this carburet is destitute of hydrogen.

When the compound of potash, water, and carburet of sulphur, is added to metallic solutions, precipitates of a peculiar kind, called carbo-sulphurets, are obtained. The following is a table of the colours of the precipitates:

Muriate of Cerium,	White or yellowish-white.
Sulphate of Manganese,	Greenish-gray.
Sulphate of Zinc,	White.
Permuriate of iron,	Dark red.
Submuriate of Antimony,	Orange.
Muriate of tin,	Pale orange, then brown.
Nitrate of Cobalt,	Dark olive-green, at last black.
Nitrate of lead,	A fine scarlet.
Nitrate of copper,	Dark brown.
Protomuriate of mercury,	Black.
Permuriate of mercury,	Orange.
Muriate of silver,	Reddish-brown.

Carburet of sulphur was found by Dr. Brewster to exceed all fluid bodies in refractive power, and even the solids, flint-glass, topaz, and tourmaline. In dispersive power it exceeds every fluid substance except oil of cassia, holding an intermediate place between phosphorus and balsam of tolu.

The best method of analyzing the carburet of sulphur, is to pass its vapour over ignited peroxide of iron; though the analysis was skilfully effected by MM. Berthollet, Vauquelin, and Thenard, by transmitting the vapour through a red-hot copper tube, or a porcelain one containing copper turnings. Both the first method, as employed by Berzelius, and the second, concur in showing the carburet to consist of

1 prime of carbon,	0.75	15.79
2 primes of sulphur,	4.00	84.21
	4.75	100.00

Vauquelin's experimental numbers are, from 15 to 16 carbon, and from 86 to 85 sulphur; and those of Berzelius and Marcet are 15.17 carbon, and 84.83 sulphur, in 100 parts.

Of the cold produced by the evaporation of the carburet of sulphur, the following account is given by Dr. Thomson in the third volume of his Annals, being the extract of a letter which he received from Mr. J. Murray, philosophical lecturer:—"A glass of water has remained on the table since the preceding evening, and though it might be some degrees below 32° Fahr. it indicated no disposition for congelation. A few drops of sulphuret of carbon were applied to the surface, instantly the globules became cased with a shell of icy spiculæ of retiform texture. Where they were in contact with the water, plumose branches darted from the sulphuret as from a centre to the bottom of the vessel, and the whole became solidified. The sulphuret of carbon in the interim volatilized, and during this period the spicules exhibited the colours of the solar spectrum in beautiful array."*

* **Carburetted Hydrogen Gas.** Of this compound gas, formerly called heavy inflammable air, we have two species, differing in the proportions of the constituents. The first, consisting of 1 prime equivalent of each, is carburetted hydrogen; the second, of 1 prime of carbon, and 2 of hydrogen, is subcarburetted hydrogen. 1. Carburetted hydrogen, the percarburetted hy-

drogen of the French chemists, is, according to Mr. Brande, the only definite compound of these two elements. To prepare it, we mix in a glass retort, 1 part of alcohol, and 4 of sulphuric acid, and expose the retort to a moderate heat. The gas is usually received over water: though De Saussure states that this liquid absorbs more than 1-7th of its volume of the gas. It is destructive of animal life. Its specific gravity is 0.978, according to Saussure. 100 cubic inches weigh 28.80 gr. It possesses all the mechanical properties of air. It is invisible, and void of taste and smell, when it has been washed from a little ethereous vapour. The effect of heat on this gas is curious. When passed through a porcelain tube, heated to a cherry red, it lets fall a portion of charcoal, and nearly doubles its volume. At a higher temperature it deposites more charcoal, and augments in bulk; till finally, at the greatest heat to which we can expose it, it lets fall almost the whole of its carbon, and assumes a volume 3½ times greater than it had at first. These remarkable results, observed with great care, have induced the illustrious Berthollet to conclude, with much plausibility, that hydrogen and carbon combine in many successive proportions. The transmission of a series of electric sparks through this gas, produces a similar effect with that of simple heat.

Carburetted hydrogen burns with a splendid white flame. When mixed with three times its bulk of oxygen, and kindled by a taper or the electric spark, it explodes with great violence, and the four volumes are converted into two volumes of carbonic acid. But two volumes of carbonic acid contain two volumes of oxygen. The remaining volume of oxygen therefore has been expended in forming water with two volumes of hydrogen. Hence the original volume of carburetted hydrogen was made up of these two volumes of hydrogen $= 0.1398$ (0.0694×2) + 2 volumes of gaseous carbon $= 0.8333$, constituting 1 condensed volume $= 0.9731$. By gaseous carbon is meant the vapour of this solid, as it exists in carbonic acid; the density of which vapour is found by subtracting the specific gravity of oxygen, from that of carbonic acid. Hence $1.5277 - 1.1111 = 0.4166$, represents the density of gaseous carbon. M. Thenard says, that if we mix the percarburetted hydrogen at once with three times its volume of oxygen, the eudiometer would be broken; so sudden and powerful is the expansion. The eudiometer referred to is that of Volta, which costs three guineas in Paris. My eudiometer, which does not cost three shillings, bears the explosive violence of the above mixture, without any danger. (See EUDIOMETER). When it is detonated with only an equal volume of oxygen, it expands greatly, and the two volumes become more than three and a half. In this case only 1-8th or 1-10th of a volume of carbonic acid is formed; but more than a volume and a half of carbonic oxide; a little hydrogen is consumed, but the greatest part remains untouched and mixed with the carbonic oxide. It may be separated by combustion with chlorine.

If we refer the weights above found, from the combining volumes, to the equivalent oxygen scale, we shall have the gas consisting of 1 prime of each constituent.

For 0.1398: 0.125: :8333: 0.752; now 0.125 and 0.750 represent the prime equivalents of hydrogen and carbon.

When this gas is mixed with its own bulk of chlorine, the gaseous mixture is condensed over water into a peculiar oily-looking compound. Hence this carburetted hydrogen was called by its discoverers, the associated Dutch chemists, *olefiant gas.* MM. Robiquet and Colin formed this liquid in considerable quantities, by making two currents of its constituent gases meet in a glass globe. The olefiant gas should be in rather larger quantity than the chlorine, otherwise the liquid becomes of a green colour, and acquires acid properties. When it is washed with water, and distilled off dry muriate of lime, it may be regarded as pure. It is then a limpid colourless essence of a pleasant flavour, and a sharp, sweet, and not disagreeable taste. At 45° its specific gravity is 2.2201. Its boiling point is 152°. At 49° is vapour is said to be capable of sustaining a column of 24⅔ inches of mercury. The specific gravity of the vapour is 3.4434, compared to atmospheric air. But that quantity is the sum of the densities of chlorine and olefiant gas. It will consist therefore by weight of

Olefiant gas,	0.9731	(2×0.875)	1.75
Chlorine,	2.4733		4.45
	3.4464		6.20

or two primes of the first and one of the second. Its ultimate constituents are therefore 1 chlorine, 2 carbon, and 2 hydrogen. This substance burns with a green flame, from which charcoal is deposited, and muriatic acid gas flies off. Decomposition, with similar results, is effected by passing the liquid through a red-hot porcelain tube. Its constitution probably resembles that of muriatic ether.

Olefiant gas is elegantly analyzed by heating sulphur in it over mercury. One cubic inch of it, with 2 grains of sulphur, yields two cubic inches of sulphuretted hydrogen, and charcoal is deposited. Now we know that the latter gas contains just its own volume of hydrogen.

2. Subcarburetted hydrogen. This gas is supposed to be procured in a state of definite composition, from the mud of stagnant

pools or ditches. We have only to fill a wide mouthed goblet with water, and inverting it in the ditch-water, stir the bottom with a stick. Gas rises into the goblet.

The fire-damp of mines is a similar gas to that of ditches. There is in both cases an admixture of carbonic acid, which lime or potash-water will remove. A proportion of air is also present, the quantity of which can be ascertained by analysis. By igniting acetate of potash in a gun-barrel, an analogous species of gas is obtained. According to M. Berthollet, the sp. gr. of the carburetted hydrogen from ditch mud, exclusive of the azote, is 0.5382.

Subcarburetted hydrogen is destitute of colour, taste, and smell. It burns with a yellow flame, like that of a candle. When mixed with twice its volume of oxygen and exploded, we obtain exactly its own bulk of carbonic acid, while water is precipitated. We can hence infer the composition of subcarburetted hydrogen. For of the two volumes of oxygen, one remains gaseous in the carbonic acid, and another is condensed with two volumes of hydrogen into water. 1 volume of vapour of carbon + 2 volumes of hydrogen, condensed into 1 volume, compose subcarburetted hydrogen gas. Thus in numbers,

$$\begin{array}{llrl}
1 \text{ volume of gaseous carbon} & = 0.4166 & & 0.75 = 1 \text{ prime} \\
2 \text{ do. hydrogen} & = 0.1398 & (0.125 \times 2) = & 0.25 = 2 \text{ primes} \\
\hline
 & \ 0.5564 & & 1.00
\end{array}$$

Here we see the specific gravity 0.5564, is very near the determination of Berthollet. We also perceive the compound prime to be 1.000, the same as oxygen. Berthollet says that the carburetted hydrogen obtained by exposing olefiant gas to an intense heat contains 2 of hydrogen to 1 of carbon by weight. This proportion corresponds to

12 primes of hydrogen = 1.5
And 1 do. of carbon = 0.75

As the gas of ditches and the choke-damp of mines are evidently derived from the action of water on decaying vegetable or carbonaceous matter, we can understand that a similar product will be obtained by passing water over ignited charcoal, or by heating moistened charcoal or vegetable matter in retorts. The gases are here, however, a somewhat complex mixture, as well as what we obtain by igniting pit-coal and wood in iron retorts. (See Coal Gas). The combustion of subcarburetted hydrogen with common air takes place only when they are mixed in certain proportions. If from 6 to 12 parts of air be mixed with 1 of carburetted hydrogen, we have explosive mixtures. Proportions beyond these limits will not explode. In like manner, from 1 to 2½ of oxygen, must be mixed with 1 of the combustible gas, otherwise we have no explosion. Sir H. Davy says that this gas has a disagreeable empyreumatic smell, and that water absorbs 1-30th of its volume of it.*

Carica Papaya. Papaw tree. Every part of the papaw tree, except the ripe fruit, affords a milky juice, which is used in the Isle of France as an effectual remedy for the tape-worm. In Europe, however, whither it has been sent in the concrete state, it has not answered.

The most remarkable circumstance regarding the papaw tree, is the extraction from its juice of a matter exactly resembling the flesh or fibre of animals, and hence called vegetable *fibrin;* which see.

Carmine. A red pigment prepared from cochineal. See Lake.

* **Carnelian** is a sub-species of calcedony. Its colours are white, yellow, brown, and red. It has a conchoidal fracture and a specific gravity of 2.6. It is semi-transparent, and has a glistening lustre. It consists of 94 silica, 3.5 alumina, and 0.75 oxide of iron. The finest specimens come from Cambay and Surat in India. It is found in the channels of torrents in Hindostan, in nodules of a blackish olive, passing into gray. After exposure for some weeks to the sun, these are subjected to heat in earthen pots, whence proceed the lively colours for which they are valued in jewelry. It is softer than common calcedony.*

* **Caromel.** The smell exhaled by sugar, at a calcining heat.*

Carthamus, Safflower, or Bastard Saffron. In some of the deep reddish, yellow, or orange-coloured flowers, the yellow matter seems to be of the same kind with that of the pure yellow flowers; but the red to be of a different kind from the pure red ones. Watery menstrua take up only the yellow, and leave the red, which may afterward be extracted by alcohol, or by a weak solution of alkali. Such particularly are the saffron-coloured flowers of carthamus. These after the yellow matter has been extracted by water, are said to give a tincture to ley; from which, on standing at rest for some time, a deep red fecula subsides, called safflower, and from the countries whence it is commonly brought to us, Spanish red and China lake. This pigment impregnates alcohol with a beautiful red tincture; but communicates no colour to water.

Rouge is prepared from carthamus. For this purpose the red colour is extracted by a solution of the subcarbonate of soda, and precipitated by lemon juice, previously depurated by standing. This precipitate is dried on earthen plates, mixed with talc, or French chalk, reduced to a powder by means of the leaves of shavegrass, triturated with it till they are both very fine, and then sifted. The fineness of the powder and proportion of the precipitate constitute the difference between the finer and cheaper rouge. It is likewise spread very thin on saucers, and sold in this state for dyeing.

Carthamus is used for dyeing silk of a poppy, cherry, rose, or bright orange red. After the yellow matter is extracted as above, and the cakes opened, it is put into a deal trough, and sprinkled at different times with pearl ashes, or rather soda well powdered and sifted, in the proportion of six pounds to a hundred, mixing the alkali well as it is put in. The alkali should be saturated with carbonic acid. The carthamus is then put on a cloth in a trough with a grated bottom, placed on a larger trough, and cold water poured on, till the large trough is filled. And this is repeated, with the addition of a little more alkali toward the end, till the carthamus is exhausted and becomes yellow. Lemon juice is then poured into the bath, till it is turned of a fine cherry colour, and after it is well stirred the silk is immersed in it. The silk is wrung, drained, and passed through fresh baths, washing and drying after every operation, till it is of a proper colour; when it is brightened in hot water and lemon juice. For a poppy or fire colour a slight annotta ground is first given; but the silk should not be alumed. For a pale carnation a little soap should be put into the bath. All these baths must be used as soon as they are made; and cold, because heat destroys the colour of the red feculæ.

* **CARTILAGE.** An elastic, semi-transparent, animal solid, which remains of the shape, and one-third the weight of the bones, when the calcareous salts are removed by digestion in dilute muriatic acid. It resembles coagulated albumen. Nitric acid converts it into gelatin. With alkalis it forms an animal soap. Cartilage is the primitive paste, into which the calcareous salts are deposited in the young animal. In the disease rickets, the earthy matter is withdrawn by morbid absorption, and the bones return into the state nearly of flexible cartilage. Hence arise the distortions characteristic of this disease.*

CASE-HARDENING. Steel when hardened is brittle, and iron alone is not capable of receiving the hardness steel may be brought to possess. There is nevertheless a variety of articles in which it is desirable to possess all the hardness of steel, together with the toughness of iron. These requisites are united in the art of case-hardening, which does not differ from the making of steel, except in the shorter duration of the process. Tools, utensils, or ornaments intended to be polished, are first manufactured in iron and nearly finished, after which they are put into an iron box, together with vegetable or animal coals in powder, and cemented for a certain time. This treatment converts the external part into a coating of steel, which is usually very thin, because the time allowed for the cementation is much shorter than when the whole is intended to be made into steel. Immersion of the heated pieces into water hardens the surface, which is afterward polished by the usual methods. Moxon's Mechanic Exercises, p. 56, gives the following receipt:—Cow's horn or hoof is to be baked or thoroughly dried and pulverized. To this add an equal quantity of bay salt: mix them with stale chamber-ley, or white wine vinegar: cover the iron with this mixture, and bed it in the same in loam, or enclose it in an iron box: lay it then on the hearth of the forge to dry and harden: then put it into the fire, and blow till the lump have a blood-red heat, and no higher, lest the mixture be burned too much. Take the iron out, and immerse it in water to harden.

* **CASEIC ACID.** The name which Proust gave to a substance of an acid nature, which he extracted from cheese; and to which he ascribes many of the properties of this species of food.*

* **CASSAVA.** An American plant, the *jatropha manihat*, contains the nutritive starch cassava, curiously associated with a deadly poisonous juice. The roots of *jatropha* are squeezed in a bag. The cassava remains in it; and the juice, which is used by the Indians to poison their arrows, gradually lets fall some starch of an innocent and very nutritious quality. The whole solid matter is dried in smoke, ground, and made into bread.*

* **CASSIUS'S** purple precipitate. See **GOLD.***

CASTOR. A soft grayish-yellow or light brown substance, found in four bags in the inguinal region of the beaver. In a warm air it grows by degrees hard and brittle, and of a darker colour, especially when dried in chimneys, as is usually done. According to Bouillon La Grange, it consists of a mucilage, a bitter extract, a resin, an essential oil, in which its peculiar smell appears to reside, and a flaky crystalline matter, much resembling the adipocere of biliary calculi.

Castor is regarded as a powerful antispasmodic.

CATECHU. A brown astringent substance formerly known by the name of *Japan earth.* It is a dry extract, prepared from the wood of a species of sensitive plant, the *mimosa catechu.* It is imported into this country from Bombay and Bengal. According to Sir H. Davy, who analyzed it, that from Bombay is of uniform texture, red-brown colour, and specific gravity 1.39: that from Bengal is more friable and less consistent, of a chocolate colour externally, but internally chocolate, streaked with red-brown, and specific gravity 1.28. The catechu from either place differs little in its properties. Its taste is astringent, leaving behind a sensation of sweetness. It is almost wholly soluble in water.

Two hundred grains of picked catechu from Bombay afforded 109 grains of tannin, 68 extractive matter, 13 mucilage, 10 residuum, chiefly sand and calcareous earth. The same quantity from Bengal: tannin 97 grains, extractive matter 73, mucilage 16, residual matter, being sand, with a small quantity of calcareous and aluminous earths, 14. Of the latter the darkest parts appeared to afford most tannin, the lightest most extractive matter. The Hindoos prefer the lightest coloured, which has probably most sweetness, to chew with the betel-nut.

Of all the astringent substances we know, catechu appears to contain the largest proportion of tannin, and Mr. Purkis found, that one pound was equivalent to seven or eight of oak bark for the purpose of tanning leather.

As a medicine it has been recommended as a powerful astringent, and a tincture of it is used for this purpose, but its aqueous solution is less irritating. Made into troches with gum arabic and sugar, it is an elegant preparation, and in this way is said much to assist the clearness of the voice, and to be remarkably serviceable in disorders of the throat.

* **Cat's Eye.** A mineral of a beautiful appearance, brought from Ceylon.

Its colours are gray, green, brown, red, of various shades. Its internal lustre is shining, its fracture imperfectly conchoidal, and it is translucent. From a peculiar play of light, arising from white fibres interspersed, it has derived its name. The French call the appearance *chatoyant*. It scratches quartz, is easily broken, and resists the blow-pipe.—Its sp. gr. is 2.64. Its constituents are, according to Klaproth, 95 silica, 1.75 alumina, 1.5 lime, and 0.25 oxide of iron. It is valued for setting as a precious stone.*

Caustic (Lunar.) Fused nitrate of silver. See Silver.

Causticity. All substances which have so strong a tendency to combine with the principles of organized substances, as to destroy their texture, are said to be caustic. The chief of these are the concentrated acids, pure alkalis, and the metalic salts.

* **Cautery Potential.** Caustic.*

Cawk. A term by which the miners distinguish the opaque specimens of sulphate of barytes.

***Celestine.** Native sulphate of strontites. This mineral is so named from its occasional delicate blue colour; though it is frequently found of other shades, as white, grayish and yellowish-white, and red. It occurs both massive and crystallized. Sometimes also in fibrous and stellated forms.—According to Haüy, the primitive form is a right rhomboidal prism, of 104° 48′ and 75° 12′. The reflecting goniometer makes these angles 104° and 76°. The varieties of its crystals may be referred to four or six-sided prisms, terminated by two, four, or eight-sided summits. It has a shining lustre, and is either transparent, translucent, or opaque. It scratches calcareous spar, but is scratched by fluor. It is very brittle. Its sp. gr. is 3.6. Before the blow-pipe it fuses into a white, opaque, and friable enamel.

The three subspecies are, 1st. The compact found in Montmartre near Paris, of a yellowish-gray colour, in rounded pieces, of a dull lustre, opaque, and consisting, by Vauquelin's analysis, of 91.42 sulphate of strontites, 8.33 carbonate of lime, and 0.25 oxide of iron. 2d, The fibrous, whose colours are indigo-blue and bluish-gray; sometimes white. It occurs both massive and crystallized. Shining and somewhat pearly lustre. It is translucent. Sp. grav. 8.83. 3d, The foliated, of a milk-white colour, falling into blue. Massive and in grouped crystals, of a shining lustre and straight foliated texture. Translucent. Celestine occurs most abundantly near Bristol in the red marl formation; and crystallized in red sandstone, at Inverness in Scotland.

Mr. Gruner Ober Berg of Hanover has lately favoured the world with an analysis of a crystallized celestine, found in the neigbourhood of that city, of rather peculiar composition. Its sp. gr. is only 3.59, and yet it contains a large proportion of sulphate of barytes:

Sulphate of strontites,	73.000
Sulphate of barytes,	26.166
Ferruginous clay,	0.213
Loss,	0.621
	100.000

Had the result been 75 of sulphate of strontites + 25 sulphate of barytes, we should have considered the mineral as a compound of 4 primes of the first salt + 1 of the second. Now the analysis, in my opinion, cannot be confided in, within these limits; for the mingled muriates of the earths were separated by digestion in 16 times their weight of boiling alcohol, of a strength not named. Besides, the previous perfect conversion of the sulphates into carbonates, by merely fusing the mineral with thrice its weight of carbonate of potash, is, to say the least, problematical. Dr. Thomson adapts M

Ober Berg's analysis to 7 atoms of sulphate of strontian, and 2 atoms of sulphate of barytes.*

Cement. Whatever is employed to unite or cement together things of the same or different kinds, may be called a *cement*. In this sense it includes LUTES, GLUES, and SOLDERS of every kind, which see; but it is more commonly employed to signify those of which the basis is an earth or earthy salt. See LIME. We shall here enumerate, chiefly from the Philosophical Magazine, some cements that are used for particular purposes.

Seven or eight parts of resin, and one of wax, melted together, and mixed with a small quantity of plaster of Paris, is a very good cement to unite pieces of Derbyshire spar, or other stone. The stone should be made hot enough to melt the cement, and the pieces should be pressed together as closely as possible, so as to leave as little as may be of the cement between them. This is a general rule in cementing, as the thinner the stratum of cement interposed, the firmer it will hold.

Melted brimstone used in the same way will answer sufficiently well, if the joining be not required to be very strong.

It sometimes happens, that jewellers, in setting precious stones, break off pieces by accident; in this case they join them so that it cannot easily be seen, with gum mastic, the stone being previously made hot enough to melt it. By the same medium cameos of white enamel or coloured glass are often joined to a real stone as a ground, to produce the appearance of an onyx. Mastic is likewise used to cement false backs or doublets to stones, to alter their hue.

The jewellers in Turkey, who are generally Armenians, ornament watch-cases and other trinkets with gems, by glueing them on. The stone is set in silver or gold, and the back of the setting made flat to correspond with the part to which it is to be applied. It is then fixed on with the following cement. Isinglass, soaked in water till it swells up and becomes soft, is dissolved in French brandy, or in rum, so as to form a strong glue. Two small bits of gum galbanum, or gum ammoniacum, are dissolved in two ounces of this by trituration; and five or six bits of mastic, as big as peas, being dissolved in as much alcohol as will render them fluid, are to be mixed with this by means of a gentle heat. This cement is to be kept in a phial closely stopped; and when used, it is to be liquefied by immersing the phial in hot water. This cement resists moisture.

A solution of shell lac in alcohol, added to a solution of isinglass in proof spirit, makes another cement that will resist moisture.

So does common glue melted without water, with half its weight of resin, with the addition of a little red ochre to give it a body. This is particularly useful for cementing hones to their frames.

If clay and oxide of iron be mixed with oil, according to Mr. Gad of Stockholm, they will form a cement that will harden under water.

A strong cement, insoluble in water, may be made from cheese. The cheese should be that of skimmed milk, cut into slices, throwing away the rind, and boiled till it becomes a strong glue, which however does not dissolve in the water. This water being poured off, it is to be washed in cold water, and then kneaded in warm water. This process is to be repeated several times. The glue is then to be put warm on a levigating stone, and kneaded with quicklime. This cement may be used cold, but it is better to warm it; and it will join marble, stone, or earthen-ware, so that the joining is scarcely to be discovered.

Boiled linseed oil, litharge, red lead, and white lead, mixed together to a proper consistence, and applied on each side of a piece of flannel, or even linen or paper, and put between two pieces of metal before they are brought home, or close together, will make a close and durable joint, that will resist boiling water, or even a considerable pressure of steam. The proportions of the ingredients are not material, but the more the red lead predominates, the sooner the cement will dry, and the more the white lead the contrary. This cement answers well for joining stones of any dimensions.

The following is an excellent cement for iron, as in time it unites with it into one mass. Take two ounces of muriate of ammonia, one of flowers of sulphur, and 16 of cast-iron filings or borings. Mix them well in a mortar, and keep the powder dry. When the cement is wanted for use, take one part of this mixture, twenty parts of clear iron borings or filings, grind them together in a mortar, mix them with water to a proper consistence, and apply them between the joints.

Powdered quicklime mixed with bullock's blood is often used by coppersmiths to lay over the rivets and edges of the sheets of copper in large boilers, as a security to the junctures, and also to prevent cocks from leaking.

Six parts of clay, one of iron filings, and linseed oil sufficient to form a thick paste, make a good cement for stopping cracks in iron boilers.

Temporary cements are wanted in cutting, grinding, or polishing optical glasses, stones, and various small articles of jewellery, which it is necessary to fix on blocks, or handles, for the purpose. Four ounces of resin, a quarter of on ounce of wax, and four ounces of whiting made previously red-hot, form a good cemment of this kind; as any of the above articles may be fastened to it by heating them, and removed at pleasure in the same manner, though they adhere very firmly to it when cold. Pitch, resin, and a small quantity of tallow, thickened with brick-dust, is much used at Birmingham for these purposes. Four parts of resin, one of bees wax, and one of brick dust, likewise make a good cement. This answers extremely well for fixing knives and forks in their hafts; but the manufacturers of cheap articles of this kind too commonly use resin and brick-dust alone. On some occasions, in which a very tough cement is requisite, that will not crack though exposed to repeated blows; as in fastening to a block metallic articles that are to be cut with a hammer and punch, workmen usually mix some tow with the cement, the fibres of which hold its parts together.

Mr. Singer recommends the following composition as a good cement for electrical apparatus: Five pounds of resin, one of bees wax, one of red ochre, and two table spoonfuls of plaster of Paris, all melted together. A cheaper one for cementing voltaic plates into wooden troughs is made with six pounds of resin, one pound of red ochre, half a pound of plaster of Paris, and a quarter of a pint of linseed oil. The ochre and plaster of Paris should be well dried, and added to the other ingredients, in a melted state.†

* **Cement**, for buildings. See **Mortar Cements**.*

Cementation. A chemical process, which consists in surrounding a body in the solid state with the powder of some other bodies, and exposing the whole for a time in a closed vessel, to a degree of heat not sufficient to fuse the contents. Thus iron is converted into steel by cementation with charcoal; green bottle glass is converted into porcelain by cementation with sand &c. See **Iron** and **Porcelain**.

__Cerasin.__ The name given by Dr. John of Berlin to those gummy substances which swell in cold water, but do not readily dissolve in it. Cerasin is soluble in boiling water, but separates in a jelly when the water cools. Water acidulated with sulphuric, nitric, or muriatic acid, by the aid of a gentle heat, forms a permanent solution of cerasin. Gum tragacanth is the best example of this species of vegetable product.

__Cerate.__ The compound of oil or lard with bees wax, used by surgeons to screen ulcerated surfaces from the air.

__Cerin.__ A peculiar substance which precipitates, on evaporation, from alcohol, which has been digested on grated cork. Subercerin would have been a fitter name. Chevreul, the discoverer, describes this substance as consisting of small white needles, which sink and merely soften in boiling water. 1000 parts of boiling alcohol dissolve 2.42 of cerin, and only 2 of wax. Nitric acid converts it into oxalic acid. It is insoluble in an alcoholic solution of potash.

__Cerin.__ The name given by Dr. John to the part of common wax which dissolves in alcohol.

*__Cerin.__ A variety of the mineral *allanite*, lately examined by Berzelius. It consists of oxide of cerium 28.19, oxide of iron 20.72, oxide of copper 0.87, silica 30.17, alumina 11.31, lime 9.12, volatile water 0.40*.

* **Cerite.** The siliciferous oxide of cerium. This rare mineral is of a rose-red or flesh-red colour, occasionally tinged with clove-brown. Its powder is reddish-gray. It is found massive and disseminated. Internal lustre resinous, but scarcely glimmering. Its fracture is fine splintery, with indeterminate fragments. It is opaque, scratches glass, gives sparks with steel, is difficult to break, scarcely yields to the knife, and gives a grayish-white streak. It is infusible before the blow-pipe; but heat changes the gray colour of the powder to yellow. It consists, by Hisinger's analysis, of 18 silica, 68.59 oxide of cerium, 2 oxide of iron, 1.25 lime, 9.6 water and carbonic acid, and 0.56 loss, in 100 parts. Klaproth found 54.5 oxide of cerium, and 34.5 silica, in the hundred parts. It is found only in the copper mine of Bastnaes near Riddarhytta in Sweden, accompanied by the ores of copper, molybdena, and bismuth. Its sp. gr. is from 4.6 to 4.9.*

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† The meal of oil cake, or the residuum of flaxseed, after the expression of the oil, is a good lute; and when mixed with clay will enable it to bear very high temperatures without cracking. It acts, no doubt, in that case, by creating pores in consequence of its carbonization.

Calcined gypsum, or sulphate of lime, when powdered and made into a paste with water, sets in a few minutes. It is more cleanly for electrical apparatus, and more easily applied than the cements above recommended.

Shell lac, in sticks, has been imposed upon the public, in Philadelphia, as a new cement of a peculiarly costly kind; and as much has been demanded for a stick, weighing a few penny weights, as would buy a pound.

Applied to potters' ware, or glass heated above the temperature of boiling water, it is an excellent cement.

The application is much facilitated, by dissolving the lac in its weight of very strong, boiling alcohol, so as to make a thick paste. This being smeared over the edges of the fractured pieces, they must be bound together and subjected to the rays of a fire, till water will boil when dropped on them. When a crack is to be mended, more spirit must be used, so that the solution may be thin enough to run in.

***Cerium.** The metal whose oxide exists in the preceding mineral.*

To obtain the oxide of the new metal, the cerite is calcined, pulverized, and dissolved in nitromuriatic acid. The filtered solution being neutralized with pure potash, is to be precipitated by tartrate of potash, and the precipitate, well washed, and afterward calcined, is oxide of cerium.

The attempts to obtain the pure metal, by igniting the oxide purified from iron by oxalic acid, in contact with tartaric acid, oil, and lampblack, have in a great measure failed. A white brittle carburet was only obtained.

Cerium is susceptible of two stages of oxidation; in the first it is white, and this by calcination becomes of a fallow-red.

The white oxide exposed to the blow-pipe soon becomes red, but does not melt, or even agglutinate. With a large proportion of borax it fuses into a transparent globule.

The white oxide becomes yellowish in the open air, but never so red as by calcination, because it absorbs carbonic acid, which prevents its saturating itself with oxygen, and retains a portion of water, which diminishes its colour.

Alkalis do not act on it; but caustic potash in the dry way takes part of the oxygen from the red oxide, so as to convert it into the white without altering its nature.

*The protoxide of cerium is composed by Hisinger of 85.17 metal + 14.83 oxygen, and the peroxide of 79.3 metal + 20.7. The protoxide has been supposed a binary compound of cerium 5.75 + oxygen 1, and the peroxide a compound of 5.75 × 2 of cerium + 3 oxygen. An alloy of this metal with iron was obtained by Vauquelin.

The salts of cerium are white or yellow coloured, have a sweet taste, yield a white precipitate with hydrosulphuret of potash, but none with sulphuretted hydrogen; a milk-white precipitate, soluble in nitric and muriatic acids, with ferroprussiate of potash and oxalate of ammonia, none with infusion of galls, and a white one with arseniate of potash.*

Equal parts of the sulphuric acid and red oxide, with four parts of water, unite by the assistance of heat into a crystalline mass, which may be completely dissolved by adding more acid, and heating them together a long time. This solution yields, by gentle evapporation, small crystals, some of an orange, others of a lemon colour. The sulphate of cerium is soluble in water only with an excess of acid. Its taste is acid and saccharine. The sulphuric acid combines readily with the white oxide, particularly in the state of carbonate. The solution has a saccharine taste, and readily affords white crystals.

Nitric acid does not readily dissolve the red oxide without heat. With an excess of acid, white deliquescent crystals are formed, which are decomposable by heat. Their taste is at first pungent, afterward very sugary. The white oxide unites more readily with the acid.

Muriatic acid dissolves the red oxide with effervescence. The solution crystallizes confusedly. The salt is deliquescent, soluble in an equal weight of cold water, and in three or four times its weight of alcohol. The flame of this solution, if concentrated, is yellow and sparkling; if not, colourless; but on agitation it emits white, red, and purple sparks.

Carbonic acid readily unites with the oxide. This is best done by adding carbonate of potash to the nitric and muriatic solution of the white oxide, when a light precipitate will be thrown down, which on drying assumes a shining silvery appearance, and consists of 23 acid + 65 oxide + 12 water.

The white oxide unites directly with tartaric acid, but requires an excess to render it soluble.

***Cerumen** of the ear. It is a yellow coloured secretion, which lines the external auditory canal, rendered viscid and concrete by exposure to air. It has a bitter taste, melts at a low heat, and evolves a slightly aromatic odour. On ignited coals, it gives out a white smoke, similar to that of burning fat, swells, emits a fetid ammoniacal odour, and is converted into a light coal. Alcohol dissolves $\frac{5}{8}$ of it, and on evaporation leaves a substance resembling the resin of bile. The $\frac{3}{8}$ which remained are albumen mixed with oil, which by incineration leave soda and phosphate of lime. Hence, the whole constituents are five; albumen, an inspissated oil, a colouring matter, soda, and calcareous phosphate.*

Ceruse, or White Lead. See **Lead.**

***Cetine.** The name given by Chevreul to spermaceti. According to Berard, who analyzed it on M. Gay-Lussac's plan, by passing its vapour through ignited peroxide of copper, *cetine* consists of 81 carbon, 6 oxygen, aud 13 hydrogen, in 100 parts.*

***Ceylanite.** This mineral, the pleonaste of Haüy, comes from Ceylon, commonly in rounded pieces, but occasionally in crystals. The primitive form of its crystals is a regular octohedron, in which form, or with the edges truncated, it frequently occurs. Its colour is indigo-blue, passing into black, which on minute inspection appears greenish. It has a rough surface, with little external lustre, but splendent internally. The fracture is perfect flat conchoidal, with very sharp-edged fragments. It scarcely scratches quartz, and is softer than spinell. It is easily broken, has a sp. gr. of 3. 77, and is infusible by the blow-pipe.*

***Chabasite.** This mineral occurs in crystals, whose primitive form is nearly a cube, since the angle at the summit is only $93\frac{1}{3}^{\circ}$. It is found in that form, and also with 6 of its edges truncated, and the truncatures united 3 and 3 at the two opposite angles, while the other six angles are truncated. It occurs also in double six-sided pyramids, applied base to base, having the six angles at the base, and the three acute edges of each pyramid truncated. It is white, or with a tinge of rose colour, and sometimes transparent. It scratches glass, fuses by the blow-pipe into a white spongy mass, and has a sp. gr. of 2.72. Its constituents are 43.33 silica, 22.66 alumina, 3.34 lime, 9.34 soda and potash, water 21. It is found in scattered crystals in the fissures of some trap rocks, and in the hollows of certain *geodes*, disseminated in the same rocks. It occurs in the quarry of Alteberg near Oberstein.*

Chalk. A very common species of calcareous earth, of an opaque white colour, very soft, and without the least appearance of a polish in its fracture. Its specific gravity is from 2.4 to 2.6, according to Kirwan. It contains a little siliceous earth, and about two per cent of clay. Some specimens, and perhaps most, contain a little iron, and Bergmann affirms that muriate of lime, or magnesia, is often found in it; for which reason he directs the powder of chalk to be several times boiled in distilled water, before it is dissolved for the purpose of obtaining pure calcareous earth.

* **Chalk (Black).** Drawing slate. The colour of this mineral is grayish or bluish-black. Massive. The principal fracture is glimmering and slaty, the cross fracture dull, and fine earthy. It is in opaque, tabular fragments, stains paper black, streak glistening, and the same colour as the surface; easily cut and broken; sp. gr. 2.4; becomes red in the fire, and falls to pieces in water. It occurs in primitive mountains, often accompanied by alum slate. It is used in crayon drawing, whence its name.*

***Chalk Stones.** Gouty concretions whose true nature was first discovered by Dr. Wollaston, and described by him in his admirable dissertation on urinary calculi, published in the Phil. Trans. for 1797. See Gouty Concretions.*

Chalk (Red). This is a clay coloured by the oxide of iron, of which it contains from 16 to 18 parts in the hundred, according to Rinman.

Chalk (Spanish). The soap rock is frequently distinguished by this name.

Characters (Chemical). The chemical characters were invented by the earlier chemists, probably with no other view than to save time in writing the names of substances that frequently occurred, in the same manner as we avoid repetitions by the use of pronouns. But the moderns seem to have considered them as relics of alchemistical obscurity, and have almost totally rejected their use. Very little of system appears in the ancient characters of chemists: the characters of Bergmann are chiefly grounded on the ancient characters, with additions and improvements. But the characters of Hassenfratz and Adet are systematical throughout. The former are exhibited in Plate III. and the latter in Plate IV.

Charcoal. When vegetable substances are exposed to a strong heat in the apparatus for distillation, the fixed residue is called charcoal. For general purposes, wood is converted into charcoal by building it up in a pyramidal form, covering the pile with clay or earth, and leaving a few air-holes, which are closed as soon as the mass is well lighted; and by this means the combustion is carried on in an imperfect manner. In the forest of Benon, near Rochelle, great attention is paid to the manufacture, so that the charcoal made there fetches 25 or 30 per cent more than any other. The wood is that of the black oak. It is taken from ten to fifteen years old, the trunk as well as the branches cut into billets about four feet long, and not split. The largest pieces, however, seldom exceed six or seven inches in diameter. The end that rests on the ground is cut a little sloping, so as to touch it merely with an edge, and they are piled nearly upright, but never in more than one story. The wood is covered all over about four inches thick with dry grass or fern, before it is enclosed in the usual manner with clay; and when the wood is charred, half a barrel of water is thrown over the pile, and earth to the thickness of five or six inches is thrown on, after which it is left four-and-twenty hours to cool. The wood is always used in the year in which it is cut.

In charring wood it has been conjectured, that a portion of it is sometimes converted into a pyrophorus, and that the explosions that happen in powder-mills are sometimes owing to this.

* Charcoal is made on the great scale, by igniting wood in iron cylinders, as I have described under Acetic Acid. When the resulting charcoal is to be used in the manufacture of gunpowder, it is essential that the last portion of vinegar and tar be suffered to escape, and that the reabsorption of the crude vapours be prevented, by cutting off the communication between the interior of the cylinders and the apparatus for condensing the pyrolignous acid, whenever the fire is withdrawn from the furnace. If this precaution be not observed, the gunpowder made with the charcoal would be of inferior quality.

In the third volume of Tilloch's Magazine, we have some valuable facts on charcoal, by Mr. Mushet. He justly observes, that the produce of charcoal in the small way, differs from that on the large scale, in which the quantity of char depends more upon the hardness, and compactness of the texture of wood, and the skill of the workman in managing the pyramid of faggots, than on the absolute quantity of carbon it contains. The following is his table of results, reduced to 100 parts, from experiments on one pound avoirdupois of wood.

Parts in 100.

	Volatile Matter.	Charcoal.	Ashes.	Charcoal by Proust.	Charcoal by Rumford.
Oak,	76.895	22.682	0.423	20.	43.00
Ash,	81 260	17.972	0.768	17.	
Birch,	80.717	17.491	1.792		
Norway Pine,	80.441	19.204	0.355	20.	44.18
				Black Ash.	
Mahogany,	73.528	25.492	0.980	25.	
Sycamore,	79.20	19.734	1.066		
				Willow.	
Holly,	78.92	19.918	1.162	17.	
				Heart of Oak,	
Scotch Pine,	83.095	16.456	0.449	19.	
Beech,	79.104	19.941	0.955		
Elm,	79.655	19.574	0.761		43.27
Walnut,	78.521	20 663	0.816		
American Maple,	79.331	19.901	0.768		42.23
				Guaiacum.	
Do. Black Beech,	77.512	21.445	1.033	24.	
Laburnum,	74.234	24 586	1.180		
					Poplar.
Lignum Vitæ,	72.643	26.857	0.500		43.57
Sallow,	80.371	18.497	1.132		
					Lime.
Chesnut,	76.304	23.280	0.416		43.59

MM. Clement and Desormes say, that wood affords one-half its weight of charcoal. I consider the statements of Mr. Mushet and M. Proust, much more correct. They coincide with the experiments to which I have referred in treating of the extraction of vinegar from wood. (See Acetic Acid.) M. Proust says, that *good* pit-coals afford 70, 75, or 80 per cent of charcoal or coak; from which only two or three parts in the hundred of ashes remain after combustion. *Tilloch's Mag.* vol. viii.*

Charcoal is black, sonorous, and brittle, and in general retains the figure of the vegetable it was obtained from. If, however, the vegetable consist for the most part of water or other fluids, these in their extrication will destroy the connexion of the more fixed parts. In this case the quantity of charcoal is much less than in the former. The charcoal of oily or bituminous substances is of a light pulverulent form, and rises in soot. This charcoal of oils is called lampblack. A very fine kind is obtained from burning alcohol.

Turf or peat has been charred lately in France, it is said by a peculiar process, and, according to the account given in Sonnini's Journal, is superior to wood for this purpose. Charcoal of turf kindles slower than that of wood, but emits more flame, and burns longer. In a goldsmith's furnace it fused eleven ounces of gold in eight minutes, while wood charcoal required sixteen. The malleability of the gold, too, was preserved in the former instance, but not in the latter. Iron heated red-hot by it in a forge, was rendered more malleable.

From the scarcity of wood in this country, pit-coal charred, is much used instead of charcoal by the name of Coak. See Carbon.

Chay, or Chaya-Root. This is the root of the *Oldenlandia umbellata*, which grows wild on the coast of Coromandel, and is likewise cultivated there for the use of the dyers and calico printers. It is used for the same purposes as madder with us, to which it is said to be far superior, giving the beautiful red so much admired in the Madras cottons.

Cheese. Milk consists of butter, cheese, a saccharine matter called sugar of milk, and a small quantity of common salt, together with much water.

If any vegetable or mineral acid be mixed with milk, the cheese separates, and, if assisted by heat, coagulates into a mass. The quantity of cheese is less when a mineral acid is used. Neutral salts, and likewise all earthy and metallic salts, separate the cheese from the whey. Sugar and gum arabic produce the same effect. Caustic alkalis will dissolve the curd by the assistance of a boiling heat, and acids occasion a precipitation again. Vegetable acids have very little solvent power upon curd. This accounts for a greater quantity of curd being obtained when a vegetable acid is used. But what answers best is rennet, which is made by macerating in water a piece of the last stomach of a calf, salted and dried for this purpose.

Scheele observed, that cheese has a considerable analogy to albumen, which it resembles in being coagulable by fire and acids, soluble in ammonia, and affording the same products by distillation or treatment with nitric acid. There are, however, certain differences between them. Rouelle observed likewise, a striking analogy between cheese and the gluten of wheat, and that found in the feculæ of green vegetables. By kneading the gluten of wheat with a little salt and a small portion of a solution of starch, he gave it the taste, smell, and unctuosity of cheese, so that after it had been kept a certain time, it was not to be distinguished from the celebrated Rochefort cheese, of which it had all the pungency. This caseous substance from gluten, as well as the cheese of milk, appears to contain acetate of ammonia, after it has been kept long enough to have undergone the requisite fermentation, as may be proved by examining it with sulphuric acid, and with potash. The pungency of strong cheese, too, is destroyed by alcohol.

* In the 11th volume of Tilloch's Magazine there is an excellent account of the mode of making Cheshire cheese, taken from the Agricultural Report of the county. "If the milk," says the reporter, "be set together very warm, the curd, as before observed, will be firm; in this case, the usual mode is to take a common case-knife, and make incisions across it, to the full depth of the knife's blade, at the distance of about one inch; and again crossways in the same manner, the incisions intersecting each other at right angles. The whey rising through these incisions is of a fine pale-green colour. The cheese-maker and two assistants then proceed to break the curd; this is performed by their repeatedly putting their hands down into the tub; the cheese-maker, with the skimming dish in one hand, breaking every part of it as they catch it, raising the curd from the bottom, and still breaking it. This part of the business is continued till the whole is broken uniformly small; it generally takes up about 40 minutes, and the curd is then left covered over with a cloth for about half an hour to subside. If the milk has been set cool together, the curd, as before mentioned, will be much more tender, the whey will not be so green, but rather of a milky appearance." The above account of cheese-making is evidently at variance with that given by Dr. Thomson in the 4th volume of his system.*

* CHEMISTRY may be defined, the science which investigates the composition of material substances, and the permanent changes of constitution which their mutual actions produce.*

* CHENOPODIUM OLIDUM. A plant remarkable, according to MM. Chevalier and Lasseigne, for containing uncombined ammonia, which is probably the vehicle of the remarkably nauseous odour which it exhales, strongly resembling that of putrid fish. When the plant is bruised with water, and the liquor expressed and afterwards distilled, we procure a fluid which contains the subcarbonate of ammonia, and an oily matter, which gives the fluid a milky appearance. If the expressed juice of the chenopodium be evaporated to the consistence of an extract, it is found to be alkaline; there seems to be acetic acid in it. Its basis is said to be of an albuminous nature. It is stated also to contain a small quantity of the substance which the French call osmazome, a little of an aromatic resin, and a bitter matter, soluble both in alcohol and water, as well as several saline bodies. The following is stated as the result of their analysis, which, however, seems somewhat complex: 1. Subcarbonate of ammonia, 2. Albumen, 3. Osmazone, 4. An aromatic resin, 5. A bitter matter, 6. Nitrate of potash in large quantity, 7. Acetate and phosphate of potash, 8. Tartrate of potash. It is said that 100 parts of the dried plant produce 18 of ashes, of which 5½ are potash.*

* CHERT. See HORNSTONE.*

* CHIASTOLITE. A mineral crystallized in four-sided, nearly rectangular prisms. On looking into the end of the prism, we perceive in the axis of it a blackish prism, surrounded by the other, which is of a grayish, yellowish, or reddish-white colour. From each angle of the interior prisms, a blackish line extends to the corresponding angle of the exterior. In each of these outer angles there is usually a small rhomboidal space, filled with the same dark substance which composes the central prism. The black matter is the same clay-slate with the rock in which the chiastolite is imbedded. Fracture, foliated with double cleavage. Translucent. Scratches glass. Rubbed on sealing-wax, it imparts negative electricity. Its sp. gr. is 2.94. Before the blow-pipe it is convertible into a whitish enamel. The only mineral with which chiastolite or macle can be confounded, were it not crystallized, is steatite; but the latter communicates positive electricity to sealing-wax. It has been found in Britanny, in the Pyrenees, in the valley of Barege, and in Galicia in Spain, near St. James of Compostella. The interior black crystal is properly an elongated four-sided pyramid.*

* CHLORATES. Compounds of chloric acid with the salifiable bases. See CHLORIC ACID.*

* **Chloric Acid.** See Acid (Chloric).*

* **Chlorides.** Compounds of chlorine with combustible bodies. See Chlorine and the respective substances.*

* **Chlorine.** The introduction of this term, marks an era in chemical science. It originated from the masterly researches of Sir H. Davy on the oxymuriatic acid gas of the French school, a substance which, after resisting the most powerful means of decomposition which his sagacity could invent, or his ingenuity apply, he declared to be, according to the true logic of chemistry, an elementary body, and not a compound of muriatic acid and oxygen, as was previously imagined, and as its name seemed to denote. He accordingly assigned to it the term chlorine, descriptive of its colour; a name now generally used. The chloridic theory of combustion, though more limited in its applications to the chemical phenomena of nature, than the antiphlogistic of Lavoisier, may justly be regarded as of equal importance to the advancement of the science itself. When we now survey the Transactions of the Royal Society for 1808, 1809, 1810, and 1811, we feel overwhelmed with astonishment at the unparalleled skill, labour, and sagacity, by which the great English chemist, in so short a space, prodigiously multiplied the objects and resources of the science, while he promulgated a new code of laws, flowing from views of elementary action, equally profound, original, and sublime. The importance of the revolution produced by his researches on chlorine, will justify us in presenting a detailed account of the steps by which it has been effected. How entirely the glory of this great work belongs to Sir H. Davy, notwithstanding some invidious attempts in this country, to tear the well-earned laurel from his brow, and transfer it to the French chemists, we may readily judge by the following decisive facts.

The second part of the Phil. Trans. for 1809 contains researches on oxymuriatic acid, its nature and combinations, by Sir H. Davy, from which I shall make a few interesting extracts.

"In the Bakerian lecture for 1808," says he, "I have given an account of the action of potassium upon muriatic acid gas, by which more than one-third of its volume of hydrogen is produced; and I have stated, that muriatic acid can in no instance be procured from oxymuriatic acid, or from dry muriates, unless water or its elements be present.

"In the second volume of the *Mémoires* D'Arcueil, MM. Gay-Lussac and Thenard have detailed an extensive series of facts upon muriatic acid, and oxymuriatic acid. Some of their experiments are similar to those I have detailed in the paper just referred to; others are peculiarly their own, and of a very curious kind; their general conclusion is, that muriatic acid gas contains about one quarter of its weight of water; and that oxymuriatic acid is not decomposable by any substances but hydrogen, or such as can form triple combinations with it.

"One of the most singular facts that I have observed on this subject, and which I have before referred to, is that charcoal, even when ignited to whiteness in oxymuriatic or muriatic acid gases, by the voltaic battery, effects no change in them, if it has been previously freed from hydrogen and moisture, by intense ignition *in vacuo*.

"This experiment, which I have several times repeated, led me to doubt of the existence of oxygen in that substance, which has been supposed to contain it, above all others, in a loose and active state; and to make a more rigorous investigation, than had hitherto been attempted for its detection."

He then proceeds to interrogate nature, with every artifice of experiment and reasoning, till he finally extorts a confession of the true constitution of this mysterious muriatic essence. The above paper, and his Bakerian lecture, read before the Royal Society in Nov. and Dec. 1810, and published in the first part of their transactions for 1811, present the whole body of evidence for the undecompounded nature of oxymuriatic acid gas, thenceforward styled chlorine, and they will be studied in every enlightened age and country, as a just and splendid pattern of inductive Baconian logic. These views were slowly and reluctantly admitted by the chemical philosophers of Europe. The hypothesis of Lavoisier, that combustion was merely the combination of oxygen with a basis, had become as favourite an idol with the learned, as the previous hypothesis of Stahl, that one phlogistic principle pervaded all combustible bodies, which was either evolved in heat and light, or quietly transferred to an incombustible, imparting that inflammability to the new substance, which its former companion had secretly lost. Stahl's idea of combustion is the more comprehensive, and may still be true; Lavoisier's as a general proposition, is certainly false.[†]

In 1812 Sir H. Davy published his Elements of Chemical Philosophy; containing a systematic account of his new doctrines concerning the combination of simple bodies.

[†] It appears to me that Stahl's doctrine is false, both as a general and particular proposition. According to him, metals are compounds of their own oxides, now known to be compounds containing metals as ingredients; and this error was extended to explain the relation between every combustible, and its compounds formed with oxygen. The doctrine of Stahl never can be true, until it ceases to be an axiom, that the less cannot contain the greater.

Chlorine is there placed in the same rank with oxygen, and finally removed from the class of acids. In 1813, M. Thenard published the first volume of his *Traité de Chimie Eleméntaire Théorique et Pratique.* This distinguished chemist, the fellow-labourer of M. Gay-Lussac, in those able researches on the alkalis and oxymuriatic acid, which form the honourable rivalry of the French school to the brilliant career of Sir H. Davy, states, at page 584. of the above volume, the composition of oxymuriatic acid as follows: "*Composition.* The oxygenated muriatic gas, contains the half of its volume of oxygen gas, not including that which we may suppose in muriatic acid. It thence follows, that it is formed of 1.9183 of muriatic acid, and 0.5517 of oxygen; for the specific gravity of oxygenated muriatic gas is 2.47, and that of oxygen gas, 1.1034." "M. Chenevix first determined the proportion of its constituent principles. MM. Gay-Lussac and Thenard determined it more exactly, and showed that we could not decompose the oxygenated muriatic gas, but by putting it in contact with a body capable of uniting with the *two* elements of this gas, or with muriatic acid. They announced at the same time, that they could explain all the phenomena which it presents, by considering it as a simple, or as a compound body. However, this last opinion appeared more probable to them. M. Davy on the contrary, embraced the first, admitted it exclusively, and sought to fortify it, by experiments which are peculiar to him." P. 585.

In the second volume of M. Thenard's work, published in 1814, he explains the mutual action of chlorine and ammonia gases solely on the oxygenous theory. "On peut démontrer par ce dernier procédé, que le gas muriatique oxigéné doit contenir lá moitié de son volume d'oxigène, uni à l'acide muriatique." P. 147.—In the 4th volume which appeared in 1816, we find the following passages: "*Oxygenated muriatic gas.* Oxygenated muriatic gas, in combining with the metals, gives rise to the neutral muriates. Now, 107.6 of oxide of silver, contain 7.6 of oxygen, and absorb 26.4 of muriatic acid, to pass to the state of neutral muriate. Of consequence, 348 of this last acid supposed dry, and 100 of oxygen, form this gas. But the sp. gr. of oxygen is 1.1034, and that of oxygenated muriatic gas is 2.47; hence, this contains the half of its volume of oxygen." P. 52.

The force of Sir H. Davy's demonstrations, pressing for six years on the public mind of the French philosophers, now begins to transpire in a note to the above passage.—"We reason here," says M. Thenard, "obviously, on the hypothesis, which consists in regarding oxygenated muriatic gas as a compound body." This pressure of public opinion becomes conspicuous at the end of the volume. Among the additions, we have the following decisive evidence, of the lingering attachment to the old theory of Lavoisier and Berthollet.—"A pretty considerable number of persons who have subscribed for this work, desiring a detailed explanation of the phenomena, which oxygenated muriatic gas presents, on the supposition that this gas is a simple body, we are now going to explain these phenomena, on this supposition, by considering them attentively. The oxygenated muriatic gas will take the name of *chlorine;* its combinations with phosphorus, sulphur, azote, metals, will be called *chlorures;* the muriatic acid, which results from equal parts in volume of hydrogen and oxygenated muriatic gases, will be *hydrochloric acid;* the superoxygenated muriatic acid, will be *chlorous acid;* and the hyperoxygenated muriatic, *chloric acid;* the first, comparable to the hydriodic acid, and the last to the iodic acid." In fact, therefore, we evidently see, that so far from the *chloridic* theory originating in France, as has been more than insinuated, it was only the researches on iodine, so admirably conducted by M. Gay-Lussac, that by their auxiliary attack of the oxygen hypothesis, eventually opened the minds of its adherents, to the evidence long ago advanced by Sir H. Davy. It will be peculiarly instructive, to give a general outline of that evidence, which has been mutilated in some systematic works on chemistry, or frittered away into fragments.

Sir H. Davy subjected oxymuriatic gas, to the action of many simple combustibles, as well as metals, and from the compounds formed, endeavoured to eliminate oxygen, by the most energetic powers of affinity and voltaic electricity, but without success, as the following abstract will show.

If oxymuriatic acid gas be introduced into a vessel exhausted of air, containing tin; and the tin be gently heated, and the gas in sufficient quantity, the tin and the gas disappear; and a limpid fluid, precisely the same as Libavius's liquor is formed: If this substance is a combination of muriatic acid and oxide of tin, oxide of tin ought to be separated from it by means of ammonia.—He admitted ammoniacal gas over mercury to a small quantity of the liquor of Libavius; it was absorbed with great heat, and no gas was generated; a solid result was obtained, which was of a dull white colour: some of it was heated, to ascertain if it contained oxide of tin; but the whole volatilized, producing dense pungent fumes.

Another experiment of the same kind, made with great care, and in which the ammonia was used in great excess, proved that the liquor of Libavius cannot be decompounded by ammonia; but that it forms a new combination with this substance.

He made a considerable quantity of the solid compound of oxymuriatic acid and phosphorus by combustion, and saturated it with ammonia, by heating it in a proper receiver filled with ammoniacal gas, on which it acted with great energy, producing much heat; and they formed a white opaque powder. Supposing that this substance was composed of the dry muriates and phosphates of ammonia; as muriate of ammonia is very volatile, and as ammonia is driven off from phosphoric acid, by a heat below redness, he conceived that, by igniting the product obtained, he should procure phosphoric acid; he therefore introduced some of the powder into a tube of green glass, and heated it to redness, out of the contact of air, by a spirit lamp; but found, to his great surprise, that it was not at all volatile nor decomposable at this degree of heat, and that it gave off no gaseous matter.

The circumstance, that a substance composed principally of oxymuriatic acid, and ammonia, should resist decomposition, or change at so high a temperature, induced him to pay particular attention to the properties of this new body.

It has been said, and taken for granted by many chemists, that when oxymuriatic acid and ammonia act upon each other, water is formed; he several times made the experiment, and was convinced that this is not the case.

He mixed together sulphuretted hydrogen in a high degree of purity, and oxymuriatic acid gas, both dried, in equal volumes. In this instance the condensation was not $\frac{1}{40}$; sulphur, which seemed to contain a little oxymuriatic acid, was formed on the sides of the vessel; no vapour was deposited; and the residual gas contained about $\frac{19}{20}$ of muriatic acid gas, and the remainder was inflammable.

When oxymuriatic acid is acted upon by nearly an equal volume of hydrogen, a combination takes place between them, and muriatic acid gas results. When muriatic acid gas is acted on by mercury, or any other metal, the oxymuriatic acid is attracted from the hydrogen, by the stronger affinity of the metal; and an oxymuriate, exactly similar to that formed by combustion, is produced.

The action of water upon those compounds, which have been usually considered as muriates, or as dry muriates, but which are properly combinations of oxymuriatic acid with inflammable bases, may be easily explained, according to these views of the subject. When water is added in certain quantities to Libavius's liquor, a solid crystallized mass is obtained, from which oxide of tin and muriate of ammonia can be procured by ammonia. In this case, oxygen may be conceived to be supplied to the tin, and hydrogen to the oxymuriatic acid.

The compound formed by burning phosphorus in oxymuriatic acid, is in a similar relation to water. If that substance be added to it, it is resolved into two powerful acids; oxygen, it may be supposed, is furnished to the phosphorus to form phosphoric acid, hydrogen to the oxymuriatic acid to form common muriatic acid gas.

He caused strong explosions from an electrical jar to pass through oxymuriatic gas, by means of points of platina, for several hours in succession; but it seemed not to undergo the slightest change.

He electrized the oxymuriates of phosphorus and sulphur for some hours, by the power of the voltaic apparatus of 1000 double plates. No gas separated, but a minute quantity of hydrogen, which he was inclined to attribute to the presence of moisture in the apparatus employed; for he once obtained hydrogen from Libavius's liquor by a similar operation. But he ascertained that this was owing to the decomposition of water adhering to the mercury; and in some late experiments made with 2000 double plates, in which the discharge was from platina wires, and in which the mercury used for confining the liquor was carefully boiled, there was no production of any permanent elastic matter.

Few substances, perhaps, have less claim to be considered as acid, than oxymuriatic acid. As yet we have no right to say that it has been decompounded; and as its tendency of combination is with pure inflammable matters, it may possibly belong to the same class of bodies as oxygen.

May it not in fact be a *peculiar* acidifying and dissolving principle, forming compounds with combustible bodies, analogous to acids containing oxygen, or oxides, in their properties and powers of combination; but differing from them, in being for the most part decomposable by water? On this idea muriatic acid may be considered as having hydrogen for its basis, and oxymuriatic acid for its acidifying principle. And the phosphoric sublimate as having phosphorus for its basis, and oxymuriatic acid for its acidifying matter. And Libavius's liquor, and the compounds of arsenic with oxymuriatic acid, may be regarded as analogous bodies. The combinations of oxymuriatic acid with lead, silver, mercury, potassium, and sodium, in this view, would be considered as a class of bodies related more to oxides than acids, in their powers of attraction.—*Bak. Lec.* 1809.

On the Combinations of the Common Metals with Oxygen and Oxymuriatic Gas.

Sir H. used in all cases small retorts of green glass, containing from three to six cubical inches, furnished with stop-cocks. The metallic substances were introduced, the retort exhausted and filled with the gas to be acted upon, heat was applied by means of a spirit lamp, and after cooling, the results were examined, and the residual gas analyzed.

All the metals he tried, except silver, lead, nickel, cobalt, and gold, when heated, burnt in the oxymuriatic gas, and the volatile metals with flame. Arsenic, antimony, tellurium, and zinc, with a white flame, mercury with a red flame. Tin became ignited to whiteness, and iron and copper to redness; tungsten and manganese to dull redness; platina was scarcely acted upon at the heat of fusion of the glass.

The product from mercury was corrosive sublimate. That from zinc was similar in colour to that from antimony, but was much less volatile.

Silver and lead produced horn-silver and horn-lead; and bismuth, butter of bismuth.

In acting upon metallic oxides by oxymuriatic gas, he found that those of lead, silver, tin, copper, antimony, bismuth, and tellurium, were decomposed in a heat below redness, but the oxides of the volatile metals more readily than those of the fixed ones. The oxides of cobalt and nickel were scarcely acted upon at a dull red heat. The red oxide of iron was not affected at a strong red heat, whilst the black oxide was readily decomposed at a much lower temperature; arsenical acid underwent no change at the greatest heat that could be given it in the glass retort, whilst the white oxide readily decomposed.

In cases where oxygen was given off, it was found exactly the same in quantity as that which has been absorbed by the metal. Thus two grains of red oxide of mercury absorbed $\frac{9}{10}$ of a cubical inch of oxymuriatic gas, and afforded 0.45 of oxygen. Two grains of dark olive oxide from calomel decomposed by potash, absorbed about $\frac{94}{10}$ of oxymuriatic gas, and afforded $\frac{24}{100}$ of oxygen, and corrosive sublimate was produced in both cases.

In the decomposition of the white oxide of zinc, oxygen was expelled exactly equal to half the volume of the oxymuriatic acid absorbed. In the case of the decomposition of the black oxide of iron, and the white oxide of arsenic, the changes that occurred were of a very beautiful kind; no oxygen was given off in either case, but butter of arsenic and arsenical acid formed in one instance, and the ferruginous sublimate and red oxide of iron in the other.

General Conclusions and Observations, illustrated by Experiments.

Oxymuriatic gas combines with inflammable bodies, to form simple binary compounds; and in these cases, when it acts upon oxides, it either produces the expulsion of their oxygen, or causes it to enter into new combinations.

If it be said that the oxygen arises from the decomposition of the oxymuriatic gas, and not from the oxides, it may be asked, why it is always the quantity contained in the oxide? and why in some cases, as those of the peroxides of potassium and sodium, it bears no relation to the quantity of gas?

If there existed any acid matter in oxymuriatic gas, combined with oxygen, it ought to be exhibited in the fluid compound of one proportion of phosphorus, and two of oxymuriatic gas; for this, on such an assumption, should consist of muriatic acid (on the old hypothesis, free from water) and phosphorous acid; but this substance has no effect on litmus paper, and does not act under common circumstances on fixed alkaline bases, such as dry lime or magnesia. Oxymuriatic gas, like oxygen, must be combined in large quantity with peculiar inflammable matter, to form acid matter. In its union with hydrogen, it instantly reddens the driest litmus paper, though a gaseous body. Contrary to acids, it expels oxygen from protoxides; and combines with peroxides.

When potassium is burnt in oxymuriatic gas, a dry compound is obtained. If potassium combined with oxygen is employed, the whole of the oxygen is expelled, and the same compound formed. It is contrary to sound logic to say, that this exact quantity of oxygen is given off from a body not known to be compound, when we are certain of its existence in another; and all the cases are parallel.

Scheele explained the bleaching powers of the oxymuriatic gas, by supposing that it destroyed colours by combining with phlogiston. Berthollet considered it as acting by supplying oxygen. He made an experiment, which seems to prove that the pure gas is incapable of altering vegetable colours, and that its operation in bleaching depends entirely upon its property of decomposing water, and liberating its oxygen.

He filled a glass globe, containing dry powdered muriate of lime, with oxymuriatic gas. He introduced some dry paper tinged with litmus that had been just heated, into another globe containing dry muriate of lime; after some time this globe was exhausted, and then connected with the globe containing the oxymuriatic gas, and by an appropriate set of stop-cocks, the paper was exposed to the action of the gas. No change of colour took place, and after two days there was scarcely a perceptible alteration.

Some similar paper dried, introduced into gas that had not been exposed to muriate of lime, was instantly rendered white.

It is generally stated in chemical books, that oxymuriatic gas is capable of being condensed and crystallized at a low temperature. He found by several experiments that this is not the case. The solution of oxymuriatic gas in water freezes more readily than pure water, but the pure gas dried by muriate of lime undergoes no change whatever, at a temperature of 40 below 0° of Fahrenheit. The mistake seems to have arisen from the exposure of the gas to cold in bottles containing moisture.

He attempted to decompose boracic and phosphoric acids by oxymuriatic gas, but without success; from which it seems probable, that the attractions of boracium and phosphorus for oxygen are stronger than for oxymuriatic gas. And from the experiments already detailed, iron and arsenic are analogous in this respect, and probably some other metals.

Potassium, sodium, calcium, strontium, barium, zinc, mercury, tin, lead, and probably silver, antimony, and gold, seem to have a stronger attraction for oxymuriatic gas than for oxygen.

"To call a body which is not known to contain oxygen, and which cannot contain muriatic acid, oxymuriatic acid, is contrary to the principles of that nomenclature in which it is adopted; and an alteration of it seems necessary to assist the progress of discussion, and to diffuse just ideas on the subject. If the great discoverer of this substance had signified it by any simple name, it would have been proper to have recurred to it; but dephlogisticated marine acid is a term which can hardly be adopted in the present advanced era of the science.

After consulting some of the most eminent chemical philosophers in this country, it has been judged most proper to suggest a name founded upon one of its obvious and characteristic properties—its colour, and to call it *chlorine*, or *chloric* gas.

Should it hereafter be discovered to be compound, and even to contain oxygen, this name can imply no error, and cannot necessarily require a change.

Most of the salts which have been called muriates, are not known to contain any muriatic acid, or any oxygen. Thus Libavius's liquor, though converted into a muriate by water, contains only tin and oxymuriatic gas; and horn-silver seems incapable of being converted into a true muriate."—*Bak*, *Lec.* 1811.

We shall now exhibit a summary view of the preparation and properties of chlorine.

Mix in a mortar 3 parts of common salt and 1 of black oxide of manganese. Introduce them into a glass retort, and add 2 parts of sulphuric acid. Gas will issue, which must be collected in the water-pneumatic trough. A gentle heat will favour its extrication. In practice, the above pasty-consistenced mixture is apt to boil over into the neck. A mixture of liquid muriatic acid and manganese is therefore more convenient for the production of chlorine. A very slight heat is adequate to its expulsion from the retort. Instead of manganese, red oxide of mercury, or puce-coloured oxide of lead, may be employed.

This gas, as we have already remarked, is of a greenish-yellow colour, easily recognized by day-light, but scarcely distinguishable by that of candles. Its odour and taste are disagreeable, strong, and so characteristic, that it is impossible to mistake it for any other gas. When we breathe it, even much diluted with air, it occasions a sense of strangulation, constriction of the *thorax*, and a copious discharge from the nostrils. If respired in larger quantity, it excites violent coughing, with spitting of blood, and would speedily destroy the individual, amid violent distress. Its specific gravity is 2.4733. This is better inferred from the specific gravities of hydrogen and muriatic acid gases, than from the direct weight of chlorine, from the impossibility of confining it over mercury. One volume of hydrogen, added to one of chlorine, form two of the acid gas. Hence, if from twice the specific gravity of muriatic gas = 2.5427, we subtract that of hydrogen = 0.0694, the difference 2.4733 is the specific gravity of chlorine. 100 cubic inches at mean pressure and temperature weigh 75½ grains. See GAS.

In its perfectly dry state, it has no effect on dry vegetable colours. With the aid of a little moisture, it bleaches them into a yellowish-white. Scheele first remarked this bleaching property; Berthollet applied it to the art of bleaching in France, and from him Mr. Watt introduced its use into Great Britain.

If a lighted wax taper be immersed rapidly into this gas, it consumes very fast, with a dull reddish flame, and much smoke. The taper will not burn at the surface of the gas. Hence, if slowly introduced, it is apt to be extinguished. The alkaline metals, as well as copper, tin, arsenic, zinc, antimony, in fine laminæ or filings, spontaneously burn in chlorine. Metallic chlorides result. Phosphorus also takes fire at ordinary temperatures, and is converted into a chloride. Sulphur may be melted in the gas without taking fire. It forms a liquid chloride, of a reddish colour. When dry, it is not altered by any change of temperature. Enclosed in a phial with a little moisture, it concretes into crystalline needles, at 40° Fahr.

According to M. Thenard, water condenses, at the temperature of 68° Fahr.

and at 29.92 barom. 1½ times its volume of chlorine, and forms *aqueous* chlorine, formerly called liquid oxymuriatic acid. This combination is best made in the second bottle of a Woulfe's apparatus, the first being charged with a little water, to intercept the muriatic acid gas, while the third bottle may contain potash-water or milk of lime, to condense the superfluous gas. M. Thenard says, that a kilogramme of salt is sufficient for saturating from 10 to 12 litres of water. These measures correspond to 2 and 1-3d libs. avoirdupois, and from 21 to 25 pints English. There is an ingenious apparatus for making aqueous chlorine, described in Berthollet's Elements of Dyeing, vol. i.; which, however, the happy substitution of slaked lime for water, by Mr. Charles Tennent of Glasgow, has superseded, for the purposes of manufacture. It congeals by cold at 40° Fahr. and affords crystallized plates, of a deep yellow, containing a less proportion of water than the liquid combination. Hence when chlorine is passed into water at temperatures under 40°, the liquid finally becomes a concrete mass, which at a gentle heat liquefies with effervescence, from the escape of the excess of chlorine. When steam and chlorine are passed together through a red-hot porcelain tube, they are converted into muriatic acid and oxygen. A like result is obtained by exposing aqueous chlorine to the solar rays; with this difference, that a little chloric acid is formed. Hence aqueous chlorine should be kept in a dark place. Aqueous chlorine attacks almost all the metals at an ordinary temperature, forming muriates or chlorides, and heat is evolved. It has the smell, taste, and colour of chlorine; and acts like it, on vegetable and animal colours. Its taste is somewhat astringent, but not in the least degree acidulous.

When we put in a perfectly dark place at the ordinary temperature, a mixture of chlorine and hydrogen, it experiences no kind of alteration, even in the space of a great many days. But if, at the same low temperature, we expose the mixture to the diffuse light of day, by degrees the two gases enter into chemical combination, and form muriatic acid gas. There is no change in the *volume* of the mixture, but the change of its *nature* may be proved, by its rapid absorbability by water, its not exploding by the lighted taper, and the disappearance of the chlorine hue. To produce the complete discoloration, we must expose the mixture finally for a few minutes to the sunbeam. If exposed at first to this intensity of light, it explodes with great violence, and instantly forms muriatic acid gas. The same explosive combination is produced by the electric spark and the lighted taper. M. Thenard says, a heat of 392° is sufficient to cause the explosion. The proper proportion is an equal volume of each gas Chlorine and nitrogen combine into a remarkable detonating compound, by exposing the former gas to a solution of an ammoniacal salt. See Nitrogen. Chlorine is the most powerful agent for destroying contagious *miasmata*. The disinfecting phials of Morveau evolve this gas. See Chlorous Oxide.* †

* Chlorite is a mineral usually friable or very easy to pulverize, composed of a multitude of little spangles, or shining small grains, falling to powder under the pressure of the fingers. There are four sub-species. 1. *Chlorite earth.* In green, glimmering and somewhat pearly scales, with a shining green streak. It adheres to the skin, and has a greasy feel. Sp. gr. 2.6. It consists of 50 silica, 26 alumina, 1.5 lime, 5 oxide of iron, 17.5 potash. This mineral is found chiefly in clay-slate, in Germany and Switzerland. At Altenberg, in Saxony, it is intermingled with sulphurets of iron and arsenic; and amphibole in mass. 2 *Common chlorite.* A massive mineral of a blackish-green colour, a shining lustre, and a foliated fracture passing into earthy. Streak is lighter green; it is soft, opaque, easily cut and broken, and feels greasy. Sp. gr. 2.83. Its constituents are 26 silica, 18.5 alumina, 8 magnesia, 43 oxide of iron, and 2 muriate of potash. 3. *Chlorite slate.* A massive, blackish-green mineral, with resinous lustre, and curve slaty or scaly-foliated fracture. Double cleavage. Easily cut. Feels somewhat greasy. Sp. gr. 2.82. It occurs particularly along with clay-slate, and is found in Corsica, Fahlun in Sweden, and Norway. 4. *Foliated chlorite.* Colour between mountain and blackish-green. Massive; but commonly crystallized in six-sided tables, in cylinders terminated by two cones, and in double cones with the bases joined. Surface streaked. Lustre shining pearly; foliated fracture, translucent on the edges; soft, sectile, and folia usually flexible. Feels rather greasy. Sp. gr. 2.82. It is found at St. Gothard, in Switzerland, and in the island of Java. Its constituents are 35 silica, 18 alumina, 29.9 magnesia, 9.7 oxide of iron, 2.7 water.*

* Chlorophane. A violet *fluor spar*, found in Siberia.*

* Chloro-carbonous Acid. The term

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† It is surprising, that I have no where met with any mention of one of the most distinctive and obvious properties of this gas. When the exterior air was about the temperature of 60°, and a mercurial thermometer detected no difference between the temperature of the chlorine and that of the surrounding medium, the hand, immersed in it, would experience a sensation of warmth, indicating 80 or 90°.

chloro-carbonic which has been given to this compound is incorrect, leading to the belief of its being a compound of chlorine and acidified charcoal, instead of being a compound of chlorine and the protoxide of charcoal. Chlorine has no immediate action on carbonic oxide, when they are exposed to each other in common day-light over mercury; not even when the electric spark is passed through them. Experiments made by Dr. John Davy, in the presence of his brother Sir H. Davy, prove that they combine rapidly when exposed to the direct solar beams, and one volume of each is condensed into one volume of the compound. The resulting gas possesses very curious properties, approaching to those of an acid. From the peculiar potency of the sunbeam in effecting this combination, Dr. Davy called it *phosgene gas*. The constituent gases, dried over muriate of lime, ought to be introduced from separate reservoirs into an exhausted globe, perfectly dry, and exposed for fifteen minutes to bright sunshine, or for twelve hours to day-light. The colour of the chlorine disappears, and on opening the stop-cock belonging to the globe under mercury recently boiled, an absorption of one-half the gaseous volume is indicated. The resulting gas possesses properties perfectly distinct from those belonging to either carbonic oxide or chlorine.

It does not fume in the atmosphere. Its odour is different from that of chlorine, something like that which might be imagined to result from the smell of chlorine combined with that of ammonia. It is in fact more intolerable and suffocating than chlorine itself, and affects the eyes in a peculiar manner, producing a rapid flow of tears, and occasioning painful sensations.

It reddens dry litmus paper; and condenses four volumes of ammonia into a white salt, while heat is evolved. This ammoniacal compound is neutral, but has no odour, but a pungent saline taste; is deliquescent, decomposable by the liquid mineral acids, dissolves without effervescing in vinegar, and sublimes unaltered in muriatic, carbonic, and sulphurous acid gases. Sulphuric acid resolves it into carbonic and muriatic acids, in the proportion of two in volume of the latter, and one of the former. Tin, zinc, antimony, and arsenic, heated in chloro-carbonous acid, abstract the chlorine, and leave the carbonic oxide expanded to its original volume. There is neither ignition nor explosion takes place, though the action of the metals is rapid. Potassium acting on the compound gas produces a solid chloride and charcoal. White oxide of zinc, with chloro-carbonous acid, gives a metallic chloride, and carbonic acid. Neither sulphur, phosphorus, oxygen, nor hydrogen, though aided by heat, produce any change on the acid gas. But oxygen and hydrogen together, in due proportions, explode in it; or mere exposure to water, converts it into muriatic and carbonic acid gases.

From its completely neutralizing ammonia, which carbonic acid does not; from its separating carbonic acid from the subcarbonate of this alkali, while itself is not separable by the acid gases, or acetic acid; and its reddening vegetable blues, there can be no hesitation in pronouncing the chloro-carbonous compound to be an acid. Its saturating powers indeed surpass every other substance. None condenses so large a proportion of ammonia.

One measure of alcohol condenses twelve of chloro-carbonous gas without decomposing it; and acquires the peculiar odour and power of affecting the eyes.

To prepare the gas in a pure state, a good air pump is required, perfectly tight stop-cocks, dry gases, and dry vessels. Its specific gravity may be inferred from the specific gravity of its constituents, of which it is the sum. Hence 2.4733 + 0.9722 = 3.4455, is the specific gravity of chloro-carbonous gas; and 100 cubic inches weigh 105.15 grains. It appears that when hydrogen, carbonic oxide, and chlorine, mixed in equal volumes, are exposed to light, muriatic and chloro-carbonous acids are formed, in equal proportions, indicating an equality of affinity.

The paper in the Phil. Trans. for 1812, from which the preceding facts are taken, does honour to the school of Sir H. Davy. MM. Gay-Lussac and Thenard, as well as Dr. Murray, made controversial investigations on the subject at the same time, but without success. M. Thenard has, however, recognized its distinct existence and properties, by the name of *carbo-muriatic* acid, in the 2d volume of his System, published in 1814, where he considers it as a compound of muriatic and carbonic acids, resulting from the mutual actions of the *oxygenated muriatic acid*, and carbonic oxide.*

* CHLOROUS and CHLORIC OXIDES, or the protoxide and deutoxide of chlorine.

Both of these interesting gaseous compounds were discovered by Sir H. Davy.

1st, The experiments which led him to the knowledge of the first, were instituted in consequence of the difference he had observed between the properties of chlorine, prepared in different modes. The paper describing the production and properties of the chlorous oxide, was published in the first part of the Phil. Trans. for 1811. To prepare it, we put chlorate of potash into a small retort, and pour in twice as much muriatic acid as will cover it, diluted with an equal volume of water. By the application of a gentle heat, the gas is evolved. It must be collected over mercury.

Its tint is much more lively, and more yellow than chlorine, and hence its illustrious discoverer named it *euchlorine*. Its smell is peculiar, and approaches to that of burnt sugar. It is not respirable. It is soluble in water, to which it gives a lemon colour. Water absorbs 8 or 10 times its volume of this gas. Its specific gravity is to that of common air nearly as 2.40 to 1; for 100 cubic inches weigh, according to Sir H. Davy, between 74 and 75 grains. If the compound gas result from 4 volumes of chlorine + 2 of oxygen, weighing 12.1154, which undergo a condensation of one-sixth, then the specific gravity comes out 2.423, in accordance with Sir H. Davy's experiments. He found that 50 measures detonated in a glass tube over pure mercury, lost their brilliant colour, and became 60 measures; of which 40 were chlorine, and 20 oxygen. Dr. Thomson states 2.407 for the sp. gr., though his own *data*, when rightly calculated upon, give 2.444.

This gas must be collected and examined with much prudence, and in very small quantities. A gentle heat, even that of the hand, will cause its explosion, with such force as to burst thin glass. From this facility of decomposition, it is not easy to ascertain the action of combustible bodies upon it. None of the metals that burn in chlorine act upon this gas at common temperatures; but when the oxygen is separated, they then inflame in the chlorine. This may be readily exhibited by first introducing into the protoxide a little Dutch foil, which will not be even tarnished; but on applying a heated glass tube to the gas in the neck of the bottle, decomposition instantly takes place, and the foil burns with brilliancy. When already in chemical union, therefore, chlorine has a stronger attraction for oxygen than for metals; but when insulated, its affinity for the latter is predominant. Protoxide of chlorine has no action on mercury, but chlorine is rapidly condensed by this metal into calomel. Thus the two gases may be completely separated. When phosphorus is introduced into the protoxide, it instantly burns, as it would do in a mixture of two volumes of chlorine and one of oxygen; and a chloride and acid of phosphorus result. Lighted taper and burning sulphur likewise instantly decompose it. When the protoxide freed from water is made to act on dry vegetable colours, it gradually destroys them, but first gives to the blues a tint of red; from which, from its absorbability by water, and the strongly acrid taste of the solution approaching to sour, it may be considered as approximating to an acid in its nature. Since 2 volumes of chlorine weigh (2 × 2.4733) 4.9466, and 1 of oxygen 1.1111; we have 4.45 + 1. = 5.45 for the prime equivalent of chlorous oxide, on the oxygen scale. The proportion by weight in 100 parts is 81.65 chlorine + 18.35 oxygen.

2d, *Deutoxide of Chlorine*, or *Chloric Oxide*. "On Thursday the 4th May, a paper by Sir H. Davy was read at the Royal Society, on the action of acids on hyper-oxymuriate of potash. When sulphuric acid is poured upon this salt in a wine-glass, very little effervescence takes place, but the acid gradually acquires an orange colour, and a dense yellow vapour, of a peculiar and not disagreeable smell, floats on the surface. These phenomena led the author to believe, that the substance extricated from the salt is held in solution by the acid. After various unsuccessful attempts to obtain this substance in a separate state, he at last succeeded by the following method: About 60 grains of the salt are triturated with a little sulphuric acid, just sufficient to convert them into a very solid paste. This is put into a retort, which is heated by means of hot water. The water must never be allowed to become boiling hot, for fear of explosion. The heat drives off the new gas, which may be received over mercury. This new gas has a much more intense colour than euchlorine. It does not act on mercury. Water absorbs more of it than of euchlorine. Its taste is astringent. It destroys vegetable blues without reddening them. When phosphorus is introduced into it, an explosion takes place. When heat is applied, the gas explodes with more violence, and producing more light than euchlorine. When thus exploded, two measures of it are converted into nearly three measures, which consist of a mixture of one measure chlorine, and two measures oxygen. Hence, it is composed of one atom chlorine and four atoms oxygen."

I have transcribed the above abstract of Sir H. Davy's paper from the number of Dr. Thomson's Annals for June 1815, in order to confront it with the following statement in his System, 5th edition, vol. i, page 189: "The deutoxide of chlorine was discovered about the same time by Sir Humphry Davy and Count Von Stadion of Vienna; but Davy's account of it was published sooner than that of Count Von Stadion. Davy's account is published in the Philosophical Transactions for 1815, p. 214. Count Von Stadion's in Gilbert's Annalen der Physick, 52. 179. published in February, 1816."

Sir H. Davy's paper bears date "Rome, February 15th, 1815." There is therefore an interval of fully *twelve* months between the transmission of Sir H. Davy's discovery for publication, and the promulgation of Count Von Stadion's paper; and an interval of nine months between the actual publication of the first, by the reading of it before the Royal Society of England, and the appearance of the second, in Gilbert's Annalen. I do not wish to insinuate that the Count copied from the English philosopher; but I maintain, that according to every principle of literary justice, the reputation of the discovery entirely belongs to Sir H. Davy.

Even the volume of the Transactions for 1815, which one is left to infer might come forth only in 1816, must have been published earlier, for Tilloch's Magazine for December 1815, contains the whole of Sir H. Davy's paper.

The preceding abstract, circulated over Europe seven or eight months before the 52d volume of Gilbert's Annalen appeared is so copious as to require few additions.

Deutoxide of chlorine has a peculiar aromatic odour, unmixed with any smell of chlorine. A little chlorine is always absorbed by the mercury during the explosion of the gas. Hence the small deficiency of the resulting measure is accounted for. At common temperatures none of the simple combustibles which Sir H. Davy tried, decomposed the gas, except phosphorus. The taste of the aqueous solution is extremely astringent and corroding, leaving for a long while a very disagreeable sensation. The action of liquid nitric acid on the chlorate of potash affords the same gas, and a much larger quantity of this acid may be safely employed than of the sulphuric. But as the gas must be procured by solution of the salt, it is always mixed with about one-fifth of oxygen.

Since two measures of this gas, at 212°, explode and form three measures of mingled gases, of which two are oxygen and one chlorine; its composition by weight is

Oxygen, 2.2222	4 primes,	4.00	47.33
Chlorine, 2.4733	1 do.	4.45	52.67
		8.45	100.00

Its specific gravity is 2.3477; and hence 100 cubic inches of it weigh about 77 grains.

Having completed the account of this interesting compound, it may be worth while to copy a note from the 190th page of Dr. Thomson's 1st volume, to show the consistency of his opinions, in one leaf of his System. "According to Count Von Stadion, its constituents are two volumes chlorine, and three volumes oxygen. This would make it a compound of one atom chlorine, and three atoms oxygen. But the properties of the substance described by the Count differ so much from those of the gas examined by Davy, that it is probable they are distinct substances." So that after all, Count Von Stadion has got a deutoxide of chlorine to himself, without interfering with Sir H. Davy's property. We shall leave him to enjoy it, with the following intimation by his commentator:—"The reader will find an account of the properties of the deutoxide of chlorine of Count Von Stadion, in the Annals of Philosophy, vol. ix. p. 22."

Chlorophile. The name lately given by MM. Pelletier and Caventou to the green matter of the leaves of plants. They obtained it, by pressing and then washing in water, the substance of many leaves, and afterwards treating it with alcohol. A matter was dissolved, which when separated by evaporation, and purified by washing in hot water, appeared as a deep green resinous substance. It dissolves entirely in alcohol, ether, oils, or akalis; it is not altered by exposure to air; it is softened by heat, but does not melt; it burns with flame, and leaves a bulky coal. Hot water slightly dissolves it. Acetic acid is the only acid that dissolves it in great quantity. If an earthy or metallic salt be mixed with the alcoholic solution, and then alkali or alkaline subcarbonate be added, the oxide or earth is thrown down in combination with much of the green substance, forming a lake. These lakes appear moderately permanent when exposed to the air. It is supposed to be a peculiar proximate principle.

The above learned term should be spelled with a *y*, chlorophyle, to signify the green of leaf, or leaf-green: chlorophile, with an *i*, has a different etymology, and a different meaning. It signifies *fond* of green.

Cholesterine. The name given by M. Chevreul to the pearly substance of human biliary calculi. It consists of 72 carbon, 6.66 oxygen, and 21.33 hydrogen, by Berard.

Cholesteric Acid. By heating cholesterine with its own weight of strong nitric acid until it ceases to give off nitrous gas, MM. Pelletier and Caventou obtained a yellow substance, which separated on cooling, and was scarcely soluble in water. When well washed, this is cholesteric acid. It is soluble in alcohol, and may be crystallized by evaporation. It is decomposed by a heat above that of boiling water, and gives products having oxygen, hydrogen, and charcoal, for their elements. It combines with bases, and forms salts. Those of soda, potash, and ammonia, are very soluble; the rest are nearly insoluble.

* **Chromium.** This rare metal may be extracted either from the native chromate of lead or of iron. The latter being cheapest and most abundant, is usually employed.

The brown chromate of iron is not acted upon by nitric acid, but most readily by nitrate of potash, with the aid of a red heat. A chromate of potash, soluble in water, is thus formed. The iron oxide thrown out of combination may be removed from the residual part of the ore by a short digestion in dilute muriatic acid. A second fusion with ¼th of nitre, will give rise to a new portion of chromate of patash. Having decomposed the whole of the ore, we saturate the alkaline excess with nitric acid, evaporate and crystallize. The pure crystals dissolved in water, are to be added to a solution of neutral nitrate of mercury; whence by complex affinity, red chromate of mercury precipitates. Moderate ignition expels the mercury from the chromate, and the remaining chromic acid may be reduced to the metallic state, by being exposed, in contact of the charcoal from sugar, to a violent heat.

Chromium thus procured, is a porous mass of agglutinated grains. It is very brittle, and of a grayish-white, intermediate between tin and steel. It is sometimes obtained in needleform crystals, which cross each other in all directions. Its sp. gravity is 5.9. It is susceptible of a feeble magnetism. It resists all the acids except nitro-muriatic, which, at a boiling heat, oxidizes it and forms a muriate. M. Thenard describes only one oxide of chromium; but there are probably two, besides the acid already described.

1. The protoxide is green, infusible, indecomposable by heat, reducible by voltaic electricity, and not acted on by oxygen or air. When heated to dull redness with the half of its weight of potassium or sodium, it forms a brown matter, which, cooled and exposed to the air, burns with flame, and is transformed into chromate of potash or soda, of a canary-yellow colour. It is this oxide which is obtained by calcining the chromate of mercury in a small earthen retort for about ¾ of an hour. The beak of the retort is to be surrounded with a tube of wet linen, and plunged into water, to facilitate the condensation of the mercury. The oxide, newly precipitated from acids, has a dark green colour, and is easily redissolved; but exposure to a dull red heat ignites it, and renders it denser, insoluble, and of a light green colour. This change arises solely from the closer aggregation of the particles, for the weight is not altered.

2. The deutoxide is procured by exposing the protonitrate to heat, till the fumes of nitrous gas cease to issue. A brilliant brown powder, insoluble in acids, and scarcely soluble in alkalis, remains. Muriatic acid digested on it, exhales chlorine, showing the increased proportion of oxygen in this oxide.

3. The tritoxide has been already described among the acids. It may be directly procured by adding nitrate of lead to the above nitrochromate of potash, and digesting the beautiful orange precipitate of chromate of lead with moderately strong muriatic acid, till its power of action be exhausted. The fluid produced is to be passed through a filter, and a little oxide of silver, very gradually added, till the whole solution becomes of a deep red tint. This liquor, by slow evaporation, deposites small ruby-red crystals, which are the hydrated chromic acid. The prime equivalent of chromic acid deduced from the chromates of barytes and lead by Berzelius, is 6.544, if we suppose them to be neutral salts. According to this chemist, the acid contains double the oxygen that the green oxide does. But if these chromates be regarded as subsalts, then the acid prime would be 13.088, consisting of 6 oxygen + 7.088, metal; while the protoxide would consist of 3 oxygen+7.088 metal; and the deutoxide, of an intermediate proportion.*

* **Chrysoberyl.** *Cymophane* of Haüy. This mineral is usually got in round pieces about the size of a pea, but it is found crystallized in eight-sided prisms, terminated by six-sided summits. Colour, asparagus green; lustre, vitreous; fracture, conchoidal; it is semi-transparent, and brittle, but scratches quartz and beryl. Sp. gr. 3.76. It is infusible before the blow-pipe. It has double refraction, and becomes electric by friction. Its primitive form is a rectangular parallelopiped. Its constituents, according to Klaproth, are 71 alumina, 18 silica, 6 lime, and 1½ oxide of iron.

The summits of the prisms of chrysoberyl, are sometimes so cut into facettes, that the solid acquires 28 faces. It is found at Brazil, Ceylon, Connecticut, and perhaps Nertschink in Siberia. This mineral has nothing to do with the chrysoberyl of Pliny, which was probably a variety of beryl of a greenish-yellow colour.*

Chrysocolla. The Greek name for borax.

***Chrysolite.** *Peridot* of Haüy. Topaz of the ancients, while our topaz is their chrysolite. Chrysolite is the least hard of all the gems. It is scratched by quartz and the file. Its crystals are well formed compressed prisms, of eight sides at least, terminated by a wedged form or pyramidal summit, truncated at the apex. Its primitive form is a right prism, with a rectangular base. It has a strong double refraction, which is observed in looking across one of the large sides of the summit, and the opposite face of the prism. The lateral planes are longitudinally streaked. The colour is pistachio green, and other shades. External lustre splendent. Transparent; fracture, conchoidal. Scratches feldspar. Brittle. Sp. gr. 3.4. With borax, it fuses into a pale green glass. Its constituents are 39 silica, 43.5 magnesia, 19 of oxide of iron, according to Klaproth; but Vauquelin found 38, 50.5, and 9.5. Chrysolite comes from Egypt, where it is found in alluvial strata. It has also been found in Bohemia, and in the circle of Bunzlau.*

***Chrysoprase.** A variety of calcedony.

It is either of an apple or leek-green colour. Its fracture is even, waxy, sometimes a little splintery. Translucent, with scarcely any lustre. Softer than calcedony, and rather tough. Sp. gr. 2.5. A strong heat whitens it. It consists of 96.16 silica, 0.08 alumina, 0.83 lime, 0.08 oxide of iron, and 1 oxide of nickel, to which it probably owes its colour. It has been found hitherto only at Kosemütz in Upper Silesia. The mountains which enclose it, are composed chiefly of serpentine, potstone, talc, snd other unctuous rocks that almost all contain magnesia. It is found in veins or interrupted beds in the midst of a green earth which contains nickel. It is used in jewellery.*

* **Chusite.** A mineral found by Saussure in the cavities of porphyries in the environs of Limbourg. It is yellowish or greenish and translucent; its fracture is sometimes perfectly smooth, and its lustre greasy; at other times it is granular. It is very brittle. It melts easily into a translucid enamel, enclosing air bubbles. It dissolves entirely and without effervescence in acids.*

* **Chyle.** By the digestive process in the stomach of animals, the food is converted into a milky fluid, called *chyme*, which passing into the intestines is mixed with pancreatic juice and bile, and thereafter resolved into chyle and feculent matter. The former is taken up by the lacteal absorbent vessels of the intestines, which coursing along the mesenteric web, terminate in the thoracic duct. This finally empties its contents into the *vena cava*.

Chyle taken soon after the death of an animal, from the thoracic duct, resembles milk in appearance. It has no smell, but a slightly acido-saccharine taste; yet it blues reddened litmus paper, by its unsaturated alkali. Soon after it is drawn from the duct, it separates by coagulation into a thicker and thinner matter. 1. The former, or curd, seems intermediate between albumen and fibrin. Potash and soda dissolve it, with a slight exhalation of ammonia. Water of ammonia forms with it a reddish solution. Dilute sulphuric acid dissolves the *coagulum;* and very weak nitric acid changes it into adipocere. By heat, it is converted into a charcoal of difficult incineration, which contains common salt and phosphate of lime, with minute traces of iron. 2. From the serous portion, heat, alcohol, and acids, precipitate a copious coagulum of albumen. If the alcohol be hot, a little matter analogous to the substance of brain is subsequently deposited. By evaporation and cooling, Mr. Brande obtained crystals analogous to the sugar of milk. Dr. Marcet found the chyle of graminivorous animals thinner and darker, and less charged with albumen, than that of carnivorous. In the former, the weight of the fluid part to that of the coagulum was nearly 2 to 1; but a serous matter afterwards oozed out, which reduced the clot to a very small volume.*

* **Chyme.** Dr. Marcet examined chyme from the stomach of a turkey. It was a homogeneous, brownish opaque pulp, having the smell peculiar to poultry. It was neither acid nor alkaline, and left one-fifth of solid matter by evaporation. It contained albumen. From the incineration of 1000 parts, 12 parts of charcoal resulted, in which iron, lime, and an alkaline muriate were distinguished. See Digestion.*

Cimolite, or Cimolian Earth. The *cimolia* of Pliny, which was used both medicinally and for cleaning cloths by the ancients, and which has been confounded with fullers' earth and tobacco-pipe clay, has lately been brought from Argentiera, the ancient Cimolus by Mr. Hawkins, and examined by Klaproth.

It is of a light grayish-white colour, acquiring superficially a reddish tint by exposure to the air; massive; of an earthy, uneven, more or less slaty fracture; opaque; when shaved with a knife, smooth and of a greasy lustre; tenacious, so as not without difficulty to be powdered or broken; and adhering pretty firmly to the tongue. Its specific gravity is 2. It is immediately penetrated by water, and developes itself into thin laminæ of a curved slaty form. Triturated with water it forms a pappy mass; and 100 grains will give three ounces of water the appearance and consistence of a thickish cream. If left to dry after being thus ground, it detaches itself in hard bands, somewhat flexible, and still more difficult to pulverize than before.

It appeared on analysis to consist of silex 63, alumina 23, oxide of iron 1.25, water 12.

Ground with water, and applied to silk and woollen, greased with oil of almonds, the oil was completely discharged by a slight washing in water, after the stuffs had been hung up a day to dry, without the least injury to the beauty of the colour. Mr. Klaproth considers it as superior to our best fullers' earth; and attributes its properties to the minutely divided state of the silex, and its intimate combination with the alumina. It is still used by the natives of Argentiera for the same purposes as of old.

According to Olivier the island of Argentiera is entirely volcanic, and the cimolian earth is produced by a slow and gradual decomposition of the porphyries, occasioned by subterranean fires. He adds, that he collected specimens of it in all the states through which it passes.

* **Cinchona.** The quinquina and kina of the French, is the bark of several species of cinchona, which grow in South America. Of this bark there are three varieties, the red, the yellow, and the pale.

1. The red is in large, easily pulverized

pieces, which furnish a reddish-brown powder, having a bitter astringent taste. The watery infusion reddens vegetable blues, from some free citric acid. It contains also muriates of ammonia and lime. The bark contains extractive, resin, bitter principle, and tannin. 2. The *yellow Peruvian* bark, was first brought to this country about the year 1790; and it resembles pretty closely in composition, the red species, only it yields a good deal of kinate of lime in plates. 3. The pale cinchona is that generally employed in medical practice, as a tonic and febrifuge. M. Vauquelin made infusions of all the varieties of cinchona he could procure, using the same quantities of the barks and water, and leaving the powders infused for the same time. He observed, 1. That certain infusions were precipitated abundantly by infusion of galls, by solution of glue, and tartar emetic. 2. That some were precipitated by glue, but not by the two other reagents; and 3. That others were, on the contrary, by nutgalls and tartar emetic, without being affected by glue. 4. And that there were some which yielded no precipitate by nutgalls, tannin, or emetic tartar. The cinchonas that furnished the first infusion were of excellent quality; those that afforded the fourth were not febrifuge, while those that gave the second and third, were febrifuge, but in a smaller degree than the first. Besides mucilage, kinate of lime, and woody fibre, he obtained in his analyses, a resinous substance, which appears not to be identic in all the species of bark. It is very bitter; very soluble in alcohol, in acids and alkalis; scarcely soluble in cold water, but more soluble in hot. It is this body which gives to infusions of cinchona, the property of yielding precipitates by emetic tartar, galls, gelatin; and in it, the febrifuge virtue seems to reside. It is this substance in part, which falls down, on cooling decoctions of cinchona, and from concentrated infusions. A table of precipitations by glue, tannin, and tartar emetic, from infusions of different barks, has been given by M. Vauquelin; but as the particular species are difficult to define, we shall not copy it.*

CINCHONIN. See the preceding article.

CINNABAR. An ore of mercury, consisting of that metal united with sulphur.

* CINNAMON STONE. The colours of this rare mineral are blood-red, and hyacinth-red, passing into orange-yellow. It is found always in roundish pieces; lustre splendent; fracture imperfect conchoidal; fragments angular; transparent and semitransparent; scratches quartz with difficulty; somewhat brittle; sp. gr. 3.53; fuses into a brownish-black enamel. Its constituents are 38.8 silica, 21.2 alumina, 31.25 lime, and 6.5 oxide of iron. It is found in the sand of rivers, in Ceylon.*

CIPOLIN. The cipolin from Rome is a green marble with white zones: it gives fire with steel, though difficultly. One hundred parts of it contain 67.8 of carbonate of lime; 25 of quartz; 8 of schistus; 0.2 of iron, beside the iron contained in the schistus. The cipolin from Autun, 83 parts carbonate of lime, 12 of green mica, and one of iron.

* CISTIC OXIDE. A peculiar animal product, discovered by Dr. Wollaston. It constitutes a variety of urinary CALCULUS, which see.*

* CITRIC ACID. Acid of limes. It has been found nearly unmixed, with other acids, not only in lemons, oranges and limes, but also in the berries of *vaccinium oxycoccos*, or cranberry, *vaccinium vitis idæa*, or red whortleberry, of birdcherry, nightshade, hip, in unripe grapes and tamarinds. Gooseberries, currants, bilberries, beamberries, cherries, strawberries, cloudberries, and raspberries, contain citric acid mixed with an equal quantity of malic acid. The onion yields citrate of lime. See ACID (CITRIC).*

CIVET is collected betwixt the anus and the organs of generation of a fierce carnivorous quadruped met with in China and the East and West Indies, called a civet-cat, but bearing a greater resemblance to a fox or marten than a cat.

Several of these animals have been brought into Holland, and afford a considerable branch of commerce, particularly at Amsterdam. The civet is squeezed out, in summer every other day, in winter twice a week: the quantity procured at once is from two scruples to a drachm, or more. The juice thus collected is much purer and finer than that which the animal sheds against shrubs or stones in its native climates.

Good civet is of a clear yellowish or brownish colour, not fluid, nor hard, but about the consistence of butter or honey, and uniform throughout; of a very strong smell; quite offensive when undiluted; but agreeable when only a small portion of civet is mixed with a large one of other substances.

* Civet unites with oils, but not with alcohol. Its nature is therefore not resinous.*

CLARIFICATION is the process of freeing a fluid from heterogeneous matter or feculencies, though the term is seldom applied to the mere mechanical process of straining, for which see FILTRATION.

Albumen, gelatin, acids, certain salts, lime, blood, and alcohol, in many cases serve to clarify fluids, that cannot be freed from their impurities by simple percolation.

Albumen or gelatin, dissolved in a small portion of water, is commonly used for fining vinous liquors, as it inviscates the feculent matter, and gradually subsides with it to the bottom. Albumen is particularly used for fluids, with which it will combine when cold, as sirups; it being coagulated by the heat, and then rising in a scum with the dregs.

Heat alone clarifies some fluids, as the juices of plants, in which however the albumen they contain is probably the agent.

A couple of handfuls of marl, thrown into the press, will clarify cyder, or water-cyder.

Clay (Pure). See Alumina.

* Clay. The clays being opaque and non-crystallized bodies, of dull fracture, afford no good principle for determining their species; yet as they are extensively distributed in nature, and are used in many arts, they deserve particular attention. The argillaceous minerals are all sufficiently soft to be scratched by iron; they have a dull or even earthy fracture; they exhale, when breathed on, a peculiar smell called argillaceous. The clays form with water a plastic paste, possessing considerable tenacity, which hardens with heat, so as to strike fire with steel. Marls and chalks also soften in water, but their paste is not tenaceous, nor does it acquire a siliceous hardness in the fire. The affinity of the clays for moisture is manifested by their sticking to the tongue, and by the intense heat necessary to make them perfectly dry. The odour ascribed to clays breathed upon, is due to the oxide of iron mixed with them. Absolutely pure clays emit no smell.

1. *Porcelain earth*, the kaolin of the Chinese.—This mineral is friable, meagre to the touch, and, when pure, forms with difficulty a paste with water. It is infusible in a porcelain furnace. It is of a pure white, verging sometimes upon the yellow or flesh-red. Some present particles of mica, which betray their origin to be from feldspar or graphic granite. It scarcely adheres to the tongue. Sp. gr. 2.2. It is found in primitive mountains, amid blocks of granite, forming interposed strata. Kaolins are sometimes preceded by beds of a micaceous rock of the texture of gneiss, but red and very friable. This remarkabe disposition has been observed in the kaolin quarries of China, in those of Alençon, and of Saint Yriex near Limoges. The constituents of kaolin are 52 silica, 47 alumina, 0.33 oxide of iron; but some contain a notable proportion of water in their recent state. The Chinese and Japanese kaolins are whiter and more unctuous to the touch than those of Europe. The Saxon has a slight tint of yellow or carnation, which disappears in the fire, and therefore is not owing to metallic impregnation. At Saint Yriex the kaolin is in a stratum and also in a vein, amid blocks of granite, or rather the feldspar rock, which the Chinese call petuntze. The Cornish kaolin is very white and unctuous to the touch, and obviously is formed by the disintegration of the feldspar of granite.

2. *Potters' clay, or plastic clay*—The clays of this variety are compact, smooth, and almost unctuous to the touch, and may be polished by the finger when they are dry. They have a great affinity for water, form a tenacious paste, and adhere strongly to the tongue. The paste of some is even slightly transparent. They acquire great solidity, but are infusible in the porcelain furnace. This property distinguishes them from common clays, employed for coarse earthen ware. Some of them remain white, or become so in a high heat; others turn red. Sp. gr. 2. The slaty potters' clay of Werner has a dark ash-gray colour; principal fracture imperfectly conchoidal, cross fracture earthy; fragments tabular, rather light, and feels more greasy than common potters' clay. Vauquelin's analysis of the plastic clay of Forges-les-Eaux, employed for making glass-house pots, as well as pottery, gave 16 alumina, 63 silica, 1 lime, 8 iron, and 10 water. Another potters' clay gave 33.2 and 43.5 of alumina and silica, with 3.5 lime.

3. *Loam.*—This is an impure potters' clay mixed with mica and iron ochre. Colour yellowish-gray, often spotted yellow and brown. Massive, with a dull glimmering lustre from scales of mica. Adheres pretty strongly to the tongue, and feels slightly greasy. Its density is inferior to the preceding.

4. *Variegated clay.*—Is striped or spotted with white, red, or yellow colours. Massive, with an earthy fracture, verging on slaty. Shining streak. Very soft, sometimes even friable. Feels slightly greasy, and adheres a little to the tongue. Sectile. It is found in Upper Lusatia.

5. *Slate clay.*—Colour gray, or grayish-yellow. Massive. Dull or glimmering lustre, from interspersed mica. Slaty fracture, approaching sometimes to earthy. Fragments tabular. Opaque, soft, sectile, and easily broken. Sp. gr. 2.6. Adheres to the tongue, and breaks down in water. It is found along with coal, and in the floetz trap formation.

6. *Claystone.*—Colour gray, of various shades, sometimes red, and spotted or striped. Massive. Dull lustre, with a fine earthy fracture, passing into fine grained uneven, slaty or splintery. Opaque, soft, and easily broken. Does not adhere to the tongue, and is meagre to the touch. It has been found on the top of the Pentland hills in Scotland, and in Germany.

7. *Adhesive slate.*—Colour light greenish-gray. Internal lustre dull; fracture in the large, slaty; in the small, fine earthy. Frag

ments slaty. Opaque. Shining streak. Sectile. Easily broken or exfoliated. Adheres strongly to the tongue, and absorbs water rapidly with the emission of air bubbles, and a crackling sound. It is found at Montmartre near Paris, between blocks of impure gypsum, in large straight plates like sheets of pasteboard. It is found also at Menil Montant, enclosing menilite. Klaproth's analysis is 62.5 silica, 8 magnesia, 0.5 alumina, 0.25 lime, 4 oxide of iron, 22 water, and 0.75 charcoal. Its sp. gr. is 2.08.

8. *Polishing slate* of Werner.—Colour, cream-yellow, in alternate stripes. Massive. Lustre dull. Slaty fracture. Fragments tabular. Very soft, and adheres to the tongue. Smooth, but meagre to the touch. Sp. gr. in its dry state 0.6; when imbued with moisture 1.9. It has been found only in Bohemia. Its constituents are 79 silica, 1 alumina, 1 lime, 4 oxide of iron, and 14 water.

9. *Common clay* may be considered to be the same as *loam*.—Besides the above, we have the analyses of some pure clays, the results of which show a very minute quantity of silica, and a large quantity of sulphuric acid. Thus, in one analyzed by Bucholz, there was 1 silica, 31 alumina, 0.5 lime, 0.5 oxide of iron, 21.5 sulphuric acid, 45 water, and 0.5 loss. Simon found 19.35 sulphuric acid in 100 parts. We must regard these clays as sub-sulphates of alumina.

Clay Slate. Argillaceous Schistus—the Argillite of Kirwan. Colour, bluish-gray, and grayish black of various shades. Massive. Internal lustre shining or pearly. Fracture foliated. Fragments tabular. Streak greenish-white. Opaque. Soft. Sectile. Easily broken. Sonorous, when struck with a hard body. Sp. gr. 2.7. Its constituents are 48.6 silica, 23.5 alumina, 1.6 magnesia, 11.3 peroxide of iron, 0.5 oxide of manganese, 4.7 potash, 0.3 carbon, 0.1 sulphur, 7.6 water and volatile matter. Clay-slate melts easily by the blow-pipe into a shining scoria. This mineral is extensively distributed, forming a part of both primitive and transition mountains. The great beds of it are often cut across by thin seams of quartz or carbonate of lime, which divide them into rhomboidal masses. Good slates should not imbibe water. If they do, they soon decompose by the weather.

* **Clay Iron Stone.** See **Ores of Iron.***

* **Climate.** The prevailing constitution of the atmosphere, relative to heat, wind, and moisture, peculiar to any region. This depends chiefly on the latitude of the place, its elevation above the level of the sea, and its insular or continental position. Springs which issue from a considerable depth, and caves about 50 feet under the surface, preserve a uniform temperature through all the vicissitudes of the season. This is the mean temperature of this country. From a comparison of observations, Professor Mayer constructed the following empirical rule for finding the relation between the latitude and the mean temperature, in centesimal degrees, at the level of the sea.

'*Multiply the square of the cosine of the latitude by the constant number 29, the product is the temperature.* The variation of temperature for each degree of latitude is hence denoted centesimally with very great precision, by half the sine of double the latitude.

Latitude.	*Mean temperatures.*		*Height of curve of congelation in feet.*
	Cent.	*Fahr.*	
0°	29°	84.2°	15207
5	28.78	83.8	15095
10	28.13	82.6	14764
15	27.06	80.7	14220
20	25.61	78.1	13478
25	23.82	74.9	12557
30	21.75	71.1	11484
35	19.46	67.	10287
40	17.01	62.6	9001
45	14.50	58.1	7671
50	11.98	53.6	6334
55	9.54	49.2	5034
60	7.25	45.0	3818
65	5.18	41.3	2722
70	3.39	38.1	1778
75	1.94	35.5	1016
80	0.86	33.6	457
85	0.22	32.4	117
90	0.0	32.0	00

The following table represents the results of some interesting observations made under the direction of Mr. Ferguson of Raith, at Abbotshall in Fife, about 50 feet above the level of the sea, in latitude 56° 10′. The large and strong bulbs of the thermometers were buried in the ground at various depths, while the stems rose above the surface, for inspection.

	1816.				1817.			
	1 *foot.*	2 *feet.*	3 *feet.*	4 *feet.*	1 *foot.*	2 *feet*	3 *feet.*	4 *feet.*
January,	33°	36.3°	40.7°	43°	35.6	38.7	40.5	45.1
February,	33.7	36	39.0	42	37.0	40.0	41.6	42.7
March,	35	36.7	39.6	42.3	39.4	40.2	41.7	42.5
April,	39.7	38.4	41.4	43.8	45.0	42.4	42.6	42.6
May,	44.0	43.3	43.4	44.0	46.8	44.7	44.6	44.2
June,	51.6	50.0	47.1	45.8	51.1	49.4	47.6	47.8
July,	54.0	52.5	55.4	47.7	55.2	55.0	51.4	49.6
August,	50.0	52.5	60.6	49.4	53.4	53.9	52.0	50.0
September,	51.6	51.3	51.8	50.0	53.0	52.7	52.0	50.7
October,	47.0	49.3	49.7	49.6	45.7	49.4	49.4	49.8
November,	40.8	43.8	46.3	45.6	41.0	44.7	47.0	47.6
December,	35.7	40.0	43.0	46.0	37.9	40.8	44.9	46.4
Mean of whole year.	43.8	44.1	45.1	46.	44.9	45.9	46.2	46.6

Had the thermometers been sunk deeper, they would undoubtedly have indicated 47.7, which is the mean temperature of the place, as is shown by a copious spring.

The lake of Geneva, at the depth of 1000 feet, was found by Saussure to be 42°; and below 160 feet from the surface there is no monthly variation of temperature. The lake of Thun, at 370 of depth, and Lucerne at 640, had both a temperature of 41°, while the waters at the surface indicated respectively 64° and 68½° Fahr. Barlocci observed, that the Lago Sabatino, near Rome, at the depth of 490 feet, was only 44½°, while the thermometer stood on its surface at 77°. Mr. Jardine has made accurate observations on the temperatures of some of the Scottish lakes, by which it appears, that the temperature continues uniform all the year round, about 20 fathoms under the surface. In like manner, the mine of Dannemora in Sweden, which presents an immense excavation, 200 or 300 feet deep, was observed at a period when the working was stopped, to have great blocks of ice lying at the bottom of it. The bottom of the main shaft of the silver mine of Kongsberg in Norway, about 300 feet deep, is covered with perpetual snow. Hence, likewise, in the deep crevices on Ætna and the Pyrenees, the snows are preserved all the year round. It is only, however, in such confined situations that the lower strata of air are thus permanently cold. In a free atmosphere, the gradation of temperature is reversed, or the upper regions are colder, in consequence of the increased capacity for heat of the air, by the diminution of the density. In the milder climates, it will be sufficiently accurate, in moderate elevations, to reckon an ascent of 540 feet for each centesimal degree, or 100 yards for each degree on Fahrenheit's scale, of diminished temperature. Dr. Francis Buchanan found a spring at Chitlong, in the lesser valley of Nepal, in Upper India, which indicated the temperature of 147 centesimal degrees, which is 8.1° below the standard, for its parallel of latitude, 27° 38′. Whence, 8.1 × 540 = 4374 feet, is the elevation of that valley. At the height of a mile this rule would give about 33 feet too much. The decrements of temperature augment in an accelerated progression as we ascend.

Ben Nevis, the highest mountain in Great Britain, stands in latitude 57°, where the curve of congelation reaches to 4534 feet. But the altitude of the summit of the mountain is no more than 4380 feet; and therefore, during two or three weeks in July, the snow disappears. The curve of congelation must evidently rise higher in summer, and sink lower in winter, producing a zone of fluctuating ice, in which the *glaciers* are formed.

In calculating the mean temperature of countries at different distances from the equator, the warmth has been referred solely to the sun. But Mr. Bald has published, in the first number of the Edinburgh Philosophical Journal, some facts apparently incompatible with the idea of the interior temperature of the earth being deducible from the latitude of the place, or the mean temperature at the surface. The following table presents, at one view, the temperature of air and water, in the deepest coal-mines in Great Britain.

Whitehaven Colliery, county of Cumberland.

Air at the surface, - - -	55° F.
A spring at the surface, - -	49
Water at the depth of 480 feet,	60
Air at same depth, - - -	63
Air at depth of 600 feet, - -	66
Difference between water at surface and at 480 feet, - - -	11

Workington Colliery, county of Cumberland.

Air at the surface, - - -	56
A spring at the surface, - -	48

Water 180 feet down,	50° F.
Water 504 feet under the level of the ocean, and immediately beneath the Irish sea,	60
Difference between water at surface and bottom,	12

Teem Colliery, county of Durham.

Air at pit bottom, 444 feet deep,	68
Water at same depth,	61
Difference between the mean temperature of water at surface = 49°, and 444 feet down,	12

Percy Main Colliery, county of Northumberland.

Air at the surface,	42
Water about 900 feet deeper than the level of the sea, and under the bed of the river Tyne,	68
Air at the same depth,	70
At this depth Leslie's hygrometer indicated dryness = 83°.	
Difference between mean temperature of water at surface = 49°, and at 900 feet down,	19

Jarrow Colliery, county of Durham.

Air at surface,	49½
Water 882 feet down,	68
Air at same depth,	70
Air at pit bottom,	64
Difference between the mean temperature of water at surface = 49°, and 882 feet down,	19

The engine-pit of Jarrow is the deepest perpendicular shaft in Great Britain, being 900 feet to the foot of the pumps.

Killingworth Colliery, county of Northumberland.

Air at the surface,	48
Air at bottom of pit, 790 feet down,	51
Air at depth of 900 feet from the surface, after having traversed a mile and a half from the bottom of the downcast pit,	70
Water at the most distant forehead or mine, and at the great depth of 1200 feet from the surface,	74
Air at the same depth,	77
Difference betwixt the mean temperature of the water at the surface = 49°, and water at the depth of 1200 feet,	25
Distilled water boils at this depth at	213
Do. do. at surface,	210½

M. Humboldt has stated, that the temperature of the silver mine of Valenciana in New Spain is 11° above the mean temperature of Jamaica and Pondicherry, and that this temperature is not owing to the miners and their lights, but to *local* and *geological* causes. To the same local and geological causes we must ascribe the extraordinary elevation of temperature observed by Mr. Bald. He further remarks, that the deeper we descend, the drier we find the strata, so that the roads through the mines require to be watered, in order to prevent the horsedrivers from being annoyed by the dust. This fact is adverse to the hypothesis of the heat proceeding from the chemical action of water on the strata of coal. As for the pyrites intermixed with these strata, it does not seem to be ever decomposed, while it is *in situ*. The perpetual circulation of air for the respiration of the miners, must prevent the lights from having any considerable influence on the temperature of the mines.

The meteorological observations now made and published with so much accuracy and regularity in various parts of the world, will soon, it is hoped, make us better acquainted with the various local causes which modify climates, than we can pretend to be at present. The accomplished philosophical traveller, M. de Humboldt, published an admirable systematic view of the mean temperatures of different places, in the third volume of the Memoirs of the Society of Arcueil. His paper is entitled, of Isothermal Lines (lines of the same temperature), and the Distribution of Heat over the Globe. By comparing a great number of observations made between 46° and 48° N. lat., he found, that at the hour of sun-set the temperature is very nearly the mean, of that at sun-rise and two hours after noon. Upon the whole, however, he thinks, that the two observations of the extreme temperatures, will give us more correct results.

The difference which we observe in cultivated plants, depends less upon mean temperature, than upon direct light, and the serenity of the atmosphere; but wheat will not ripen if the mean temperature descend to 47.6°.

Europe may be regarded as the western part of a great continent, and subject to all those influences, which make the western sides of all continents warmer than the eastern. The same difference that we observe on the two sides of the Atlantic, exists on the two sides of the Pacific. In the north of China, the extremes of the seasons are much more felt than in the same latitudes in New California, and at the mouth of the Columbia. On the eastern side of North America, we have the same extremes as in China; New-York has the summer of Rome, and the winter of Copenhagen; Quebec has the summer of Paris, and the winter of Petersburgh. And in the same way in Pekin, which has the mean temperature of Britain; the heats of summer are greater than those at Cairo. and the cold of winter, as severe as that at Upsal. This analogy between the eastern coasts of Asia and of America, sufficiently proves, that the inequalities of the seasons, depend upon the prolongation and enlargement of the continents towards the pole, and upon the frequency of N. W. winds, and not upon the proximity of any elevated tracts of country.

Ireland, says Humboldt, presents one of the most remarkable examples of the combination of very mild winters with cold summers; the mean temperature in Hungary for the month of August is 71.6°; while in Dublin it is only 60.8°. In Belgium and Scotland, the winters are milder than at Milan.

In the article Climate, Supplement to the Encyclopædia Britannica, the following very simple rule is given, for determining the change of temperature produced by sudden rarefaction or condensation of air. *Multiply 25 by the difference between the density of air, and its reciprocal, the product will be the difference of temperature on the centigrade scale.* Thus, if the density be twice, or one half 25° × (2—½) = 37½° cent. = 67.5° Fahr. indicates the change of temperature by doubling the density or rarity of air. Were it condensed 30 times, then, by this formula, we have 749° for the elevation of temperature, or 25° $(30 - \frac{1}{30})$. But M. Gay-Lussac says, that a condensation of air into one-fifth of its volume, is sufficient to ignite tinder; a degree of heat which he states at 300° centigrade = 572° Fahr. (Journal of Science, vol. vii. p. 177). This experimental result is incompatible with Professor Leslie's Formula, which gives only 112.5°, for the heat produced by a condensation into one-fifth.

It appears very probable, that the climates of European countries were more severe in ancient times than they are at present. Cæsar says, that the vine could not be cultivated in Gaul, on account of its winter-cold. The rein-deer, now found only in the zone of Lapland, was then an inhabitant of the Pyrenees. The Tiber was frequently frozen over, and the ground about Rome covered with snow for several weeks together, which almost never happens in our times. The Rhine and the Danube, in the reign of Augustus, were generally frozen over, for several months of winter. The barbarians who overran the Roman empire a few centuries afterwards, transported their armies and wagons across the ice of these rivers. The improvement that is continually taking place in the climate of America, proves, that the power of man extends to phenomena, which from the magnitude and variety of their causes, seemed entirely beyond his controul. At Guiana, in South America, within five degrees of the line, the inhabitants living amid immense forests, a century ago, were obliged to alleviate the severity of the cold, by evening fires. Even the duration of the rainy season has been shortened by the clearing of the country, and the warmth is so increased, that a fire now would be deemed an annoyance. It thunders continually in the woods, rarely in the cultivated parts.

Drainage of the ground, and removal of forests, however, cannot be reckoned among the sources of the increased warmth of the Italian winters. Chemical writers have omitted to notice an astronomical cause of the progressive amelioration of the climates of the northern hemisphere. In consequence of the apogee (portion of the terrestrial orbit being contained between our vernal and autumnal equinox, our summer half of the year, or the interval which elapses between the sun's crossing the equator in spring, and in autumn, is about *seven* days longer than our winter half year. Hence also, one reason for the relative coldness of the southern hemisphere.*

Isothermal Bands, and Distribution of Heat over the Globe.

The temperatures are expressed in degrees of Fahrenheit's thermometer; the longitudes are counted from east to west, from the first meridian of the observatory of Paris. The mean temperature of the seasons has been calculated, so that the months of December, January, and February, form the mean temperature of the winter. The mark * is prefixed to those places, the mean temperatures of which have been determined with the most precision, generally by a mean of 8000 observations. The isothermal curves having a concave summit in Europe, and two convex summits in Asia and Eastern America, the climate is denoted to which the individual places belong:—

Isothermal bands.	Names of the places.	Position in			Mean temp. of the year.	Distribution of Heat in the different Seasons.				Maximum and Minimum.	
		Latitude.	Longitude.	Height in feet.		Mean temp. of Winter.	Mean temp. of Spring.	Mean temp. of Summer.	Mean temp of Autumn.	Mean temp. of warmest month.	Mean temp. of coldest month.
Isothermal band, from 32° to 41°.	Nain, - - -	57° 8′	63° 40′ W	0	26.8°	— 0.4°	23.7°	48.4°	33.4°	51.8°	—11.2°
	*Enontekies, -	68 30	18 27 E	1356	27.0	0.4	25.0	54.8	27.4	59.6	— 0.6
	Hospice de St. Gothard,	46 30	6 3 E	6390	30.4	18.4	26.4	45.0	31.8	46.2	15.0
	North Cape, -	71 0	23 30 E	0	32.0	23.8	29.4	43.2	32.2	50.2	22.1
	*Ulea, - - -	65 3	23 6 E	0	33.0	11.8	27.2	57.8	36.0	61.6	7.7
	*Umea, - - -	63 50	17 56 E	0	33.2	13.0	33.8	54.8	33.4	62.6	11.4
	*Petersburg, - -	59 56	27 59 E	0	38.8	17.0	38.2	62.0	38.6	65.6	8.6
	Drontheim, - -	63 24	8 2 E	0	40.0	23.8	35.2	61.4	40.1	65.0	19.8
	Moscow, - - -	55 45	35 12 E	970	40.2	10.8	44.0	67.1	38.3	70.6	6.0
	Abo, - - - -	60 27	19 58 E	0	40.4	20.8	38.3	61.8	40.6	—	—
Isothermal band, from 41° to 50°.	*Upsal, - - -	59 51	15 18 E	0	42.0	25.0	40.0	60.2	42.8	62.4	22.4
	*Stockholm, - - -	59 20	15 43 E	0	42.2	25.6	38.3	61.8	43.2	64.0	22.8
	Quebec, - - -	46 47	73 30 W	0	41.8	14.2	38.9	68.0	46.0	73.4	13.8
	Christiana, - - -	59 55	8 28 E	0	42.8	28.8	40.1	62.6	41.2	66.8	28.8
	*Convent of Peysenburg,	47 47	8 14 E	3066	43.0	28.6	42.0	58.4	43.0	59.4	30.2
	*Copenhagen, - -	55 41	10 15 E	0	45.6	30.8	41.2	62.6	48.4	65.0	27.2
	*Kendal, - - -	54 17	5 6 W	0	46.2	36.8	45.2	56.8	46.2	58.1	34.8
	Malouin Islands,	51 25	62 19 W	0	47.0	39.6	46.6	53.0	48.4	55.8	37.4
	*Prague, - - -	50 5	13 4 E	0	49.4	31.4	47.6	68.9	50.2	—	—
	Gottingen, - -	51 32	7 33 E	456	47.0	30.4	44.2	64.8	48.6	66.4	33.2
	*Zurich, - - -	47 22	6 12 E	1350	47.8	29.6	48.2	64.0	48.8	65.7	26.8
	*Edinburgh, - -	55 57	5 30 W	0	47.8	38.6	46.4	58.2	48.4	59.4	38.3
	Warsaw, - -	52 14	18 42 E	0	48.6	27.8	47.4	69.0	49.4	70.4	27.2
	*Coire, - - -	46 50	7 10 E	1876	49.0	32.4	55.4	63.4	50.4	64.6	29.6
	Dublin, - - -	53 21	8 39 W	0	49.2	39.2	47.3	59.6	50.0	61.0	35.4
	Berne, - - -	46 5	5 6 E	1650	49.3	32.0	49.0	66.6	49.8	67.2	30.6
	*Geneva, - - -	46 12	3 48 E	1080	49.3	34.9	47.6	65.0	50.0	66.6	34.2
	*Manheim, - -	49 29	6 8 E	432	50.2	33.8	49.6	67.1	49.8	68.8	33.4
	Vienna, - - -	48 12	14 2	420	50.6	32.8	51.2	69.2	50.6	70.6	26.6

Table continued from preceding page.

Isothermal band from 50° to 59°.	•Clermont, - -	45	46	0	45		1260	50.0	34.7	50.6	64.4	51.2	66.2	28.0
	•Buda, - - -	47	29	16	41		494	51.0	31.0	51.0	63.2	52.4	71.6	27.6
	Cambridge (U.S.)	42	25	73	23	W	0	50.4	34.0	47.6	64.4	49.8	72.8	29.8
	•Paris, - - -	48	50	0	0		222	51.0	38.6	49.2	64.6	51.4	65.3	36.0
	•London, - - -	51	30	2	25	W	0	50.4	39.6	48.6	63.2	50.2	64.4	37.8
	Dunkirk, - -	51	2	0	2	E	0	50.6	38.4	48.6	63.8	50.9	64.8	37.8
	Amsterdam, -	52	22	2	30	E	0	51.6	36.8	51.6	65.8	51.6	67.0	35.4
	Brussels, - -	50	50	2	2	E	0	51.8	36.6	53.2	66.2	51.0	67.4	35.6
	•Franeker, - -	52	36	4	2	E	0	51.8	36.6	51.0	67.2	54.4	69.0	32.9
	Philadelphia, -	39	56	77	36	W	0	53.4	32.2	51.4	74.0	56.6	77.0	32.7
	New York, - -	40	40	76	18	W	0	53.8	29.8	51.2	79.2	54.6	80.6	25.4
	•Cincinnati, - -	39	6	85	0	W	510	53.8	32.9	54.4	72.8	54.4	74.3	30.2
	St. Malo, - -	48	39	4	21	W	0	54.4	42.2	52.2	66.0	55.8	67.0	41.8
	Nantes, - - -	47	13	3	52	W	0	55.0	40.4	54.5	68.6	55.6	70.6	38.0
	Pekin, - - -	39	54	114	7	E	0	55.2	26.8	56.3	82.6	54.2	84.4	39.4
	•Milan, - - -	45	28	6	51	E	390	55.8	36.4	56.1	73.0	56.8	74.6	36.2
	Bourdeaux, - -	44	50	2	54	W	0	56.4	42.0	56.8	70.8	56.3	72.8	41.0
Isothermal band from 59° to 68°.	Marseilles, -	43	17	3	2	E	0	59.0	45.5	57.6	72.5	60.0	74.6	44.4
	Montpelier, -	43	36	1	32	E	0	59.4	44.0	57.0	75.8	61.0	78.2	42.0
	•Rome, - - -	41	53	10	7	E	0	60.4	45.8	57.8	75.2	62.8	77.0	42.2
	Toulon, - - -	43	7	3	30	E	0	62.0	48.4	60.8	74.8	64.4	77.0	46.4
	Nangasachi, -	32	45	127	35	E	0	60.8	39.4	57.6	83.0	64.2	86.9	37.4
	•Natchez, - -	31	28	93	50	W	180	64.8	48.6	65.4	79.2	65.8	79.7	47.0
Isothermal band from 68° to 77°.	•Funchal, - -	32	37	19	16	W	0	68.6	64.8	65.8	72.5	72.4	75.6	64.2
	Algiers, - - -	36	48	0	41	E	0	70.0	61.4	65.6	80.2	72.5	82.8	60.0
Isothermalbands above 77°.	•Cairo, - - -	30	2	28	58	E	0	72.4	58.4	73.6	85.1	70.5	85.8	55.8
	•Veracruz, - -	19	11	98	21	W	0	77.8	72.0	77.9	81.5	78.6	81.5	71.0
	•Havannah, - -	23	10	84	33	W	0	78.2	71.2	79.0	83.3	79.0	84.0	70.0
	•Cumana, - -	10	27	67	35	W	0	81.8	80.2	83.6	82.0	79.6	84.4	79.2

* **Clinkstone.** A stone of an imperfectly slaty structure, which rings like metal when struck with a hammer. Its colour is gray of various shades; it is brittle; as hard as feldspar, and translucent on the edges. It occurs in columnar and tabular concretions. Sp. gr. 2.57. Fuses easily into a nearly colourless glass. Its constituents are 57.25 silica, 25.5 alumina, 2.75 lime, 8.1 soda, 3.25 oxide of iron, 0.25 oxide of manganese, and 3 of water.—*Klaproth.* This stone generally rests on basalt. It occurs in the Ochil and Pentland hills, the Bass-rock, the islands of Mull, Lamlash, and Islay, in Scotland; the Breidden hills in Montgomeryshire, and in the Devis Mountain, in the county of Antrim. It is found in Upper Lusace and Bohemia.*

* **Clinometer.** An instrument for measuring the dip of mineral strata. It was originally invented by R. Griffith, Esq. Professor of Geology to the Dublin Society, and subsequently modified by Mr. Jardine and Lord Webb Seymour. See a description and drawing by the latter, in the third volume of the Geological Transactions. Lord Webb's instrument was a very perfect one. It was made by that unrivalled artist, Mr. Troughton.*

* **Cloud.** A mass of vapour, more or less opaque, formed and sustained at considerable heights in the atmosphere, probably by the joint agencies of heat and electricity. The first successful attempt to arrange the diversified forms of clouds, under a few general modifications, was made by Luke Howard, Esq. We shall give here a brief account of his ingenious classification.

The *simple* modifications are thus named and defined. 1. *Cirrus.* Parallel, flexuous, or diverging fibres, extensible in any or in all directions. 2. *Cumulus.* Convex or conical heaps, increasing upwards from a horizontal base. 3. *Stratus.* A widely extended, continuous horizontal sheet, increasing from below.

The *intermediate* modifications which require to be noticed are, 4. *Cirro-cumulus.* Small well-defined roundish masses, in close horizontal arrangement. 5. *Cirro-stratus.* Horizontal, or slightly inclined masses, attenuated towards a part or the whole of their circumference, bent downward, or undulated, separate or in groups, consisting of small clouds having these characters.

The *compound* modifications are, 6. *Cumulo-stratus.* The cirro-stratus, blended with the cumulus, and either appearing intermixed with the heaps of the latter, or superadding a wide-spread structure to its base.

7. *Cumulo-cirro-stratus*, vel *Nimbus.* The rain cloud. A cloud or system of clouds from which rain is falling. It is a horizontal sheet, above which the cirrus spreads, while the cumulus enters it laterally and from beneath.

The *cirrus* appears to have the least density, the greatest elevation, the greatest variety of extent and direction, and to appear earliest on serene weather, being indicated by a few threads pencilled on the sky. Before storms they appear lower and denser, and usually in the quarter opposite to that from which the storm arises. Steady high winds are also preceded and attended by *cirrus* streaks, running quite across the sky in the direction they blow in.

The cumulus has the densest structure, is formed in the lower atmosphere, and moves along with the current next the earth. A small irregular spot first appears and is as it were the nucleus on which they increase. The lower surface continues irregularly plane, while the upper rises into conical or hemispherical heaps; which may afterwards continue long nearly of the same bulk, or rapidly rise into mountains. They will begin, in fair weather, to form some hours after sunrise, arrive at their maximum in the hottest part of the afternoon, then go on diminishing and totally disperse about sunset. Previous to rain, the cumulus increases rapidly, appears lower in the atmosphere, and with its surface full of loose fleeces or protuberances. The formation of large cumuli to leeward in a strong wind, indicates the approach of a calm with rain. When they do not disappear or subside about sunset but continue to rise, thunder is to be expected in the night. The *stratus* has a mean degree of density, and is the lowest of clouds, its inferior surface commonly resting on the earth or water. This is properly the cloud of night, appearing about sunset. It comprehends all those creeping mists which in calm weather ascend in spreading sheets (like an inundation of water), from the bottom of valleys, and the surfaces of lakes and rivers. On the return of the sun, the level surface of this cloud begins to put on appearance of cumulus, the whole at the same time separating from the ground. The continuity is next destroyed, and the cloud ascends and evaporates, or passes off with the appearance of the nascent cumulus. This has long been experienced as a prognostic of fair weather.

The *cirrus* having continued for some time increasing or stationary, usually passes either to the cirro-cumulus or the cirro-stratus, at the same time descending to a lower station in the atmosphere This modification forms a very beautiful sky; is frequent in summer, an attendant on warm and dry weather. The *cirro-stratus*, when seen in the distance, frequently gives the idea of shoals of fish. It precedes wind and rain; is seen in the intervals of storms; and sometimes alternates with the cirro-cumulus in the same cloud, when the different evolutions form a curious spectacle. A judgment may be formed of the weather likely to ensue by observing which modification prevails at last. The solar and lunar *halos*, as well as the parhelion and paraselene, (mock sun and mock moon), prognostics of foul weather, are occasioned by this cloud. The cumulo-stratus precedes, and the nimbus accompanies rain. See Rain.

Mr. Howard gives a view of the origin of clouds, which will be found, accompanied with many useful remarks, in the 16th and 17th volumes of the Philos. Magazine.*

Clyssus. A word formerly used to denote the vapour produced by the detonation of nitre with any inflammable substance.

Coak. Coal is charred in the same manner as wood to convert it into charcoal. An oblong square hearth is prepared by beating the earth to a firm flat surface, and puddling it over with clay. On this, the pieces of coal are piled up, inclining toward one another, and those of the lower strata are set up on their acutest angle, so as to touch the ground with the least surface possible. The piles are usually from 30 to 50 inches high, from 9 to 16 feet broad, and contain from 40 to 100 tons of coal. A number of vents are left, reaching from top to bottom, into which the burning fuel is thrown, and they are then immediately closed with small pieces of coal beaten hard in. Thus the kindled fire is forced to creep along the bottom, and when that of all the vents is united, it rises gradually, and bursts out on every side at once. If the coal contain pyrites, the combustion is allowed to continue a considerable time after the disappearance of the smoke, to extricate the sulphur, part of which will be found in flowers on the surface: If it contain none, the fire is covered up soon after the smoke disappears, beginning at the bottom, and proceeding gradually to the top. In 50, 60, or 70 hours, the fire is in general completely covered with the ashes of char formerly made, and in 12 or 14 days the coak may be removed for use. In this way a ton of coals commonly produces from 700 to 1100 pounds of coak.

In this way the volatile products of the coal, however, which might be turned to good account, are lost: but some years ago, Lord Dundonald conceived and carried into effect, a plan for saving them. By burning the coal in a range of 18 or 20 stoves, with as little access of air as may be, at the bottom; and conducting the smoke, through proper horizontal tunnels, to a capacious close tunnel 100 yards or more in length, built of brick, supported on brick arches, and covered on the top by a shallow pond of water; the bitumen is condensed in the form of tar: 120 tons of coal yield about 3½ of tar, though some coals are said to be so bituminous as to afford 1-8th of their weight. Part of the tar is inspissated into pitch, 21 barrels of which are made of 28 of tar; and the volatile parts arising in this process are condensed into a varnish, used for mixing with colours for out-door painting chiefly. A quantity of ammonia too is collected, and used for making sal ammoniac. The cakes thus made are likewise of superior quality.

***Coal.** This very important order of combustible minerals, is divided by Professor Jameson into the following species and sub-species:

Species 1. Brown coal, already described.

Species 2. Black coal, of which there are four sub-species, slate coal, cannel coal, foliated coal, and coarse coal.

1. *Slate coal.* Its colour is intermediate between velvet-black, and dark grayish-black. It has sometimes a peacock-tail tarnish. It occurs massive, and in columnar and egg-shaped concretions. It has a resinous lustre. Principal fracture slaty; cross fracture, imperfect conchoidal. Harder than gypsum, but softer than calcareous spar. Brittle. Sp. gr. 1.26 to 1.38 It burns longer than cannel coal; cakes more or less, and leaves a slag. The constituents of the slate coal of Whitehaven, by Kirwan, are 56.8 carbon, with 43.2 mixture of asphalt and maltha, in which the former predominates. This coal is found in vast quantities at Newcastle; in the coal formation which stretches from Bolton, by Allonby and Workington, to Whitehaven. In Scotland, in the river district of Forth and Clyde; at Cannoby, Sanquhar, and Kirconnel, in Dumfries-shire; in Thuringia, Saxony, and many other countries of Germany. It sometimes passes into cannel and foliated coal.

2. *Cannel coal.* Colour between velvet and grayish-black. Massive. Resinous lustre. Fracture, flat-conchoidal, or even. Fragments trapezoidal. Hardness as in the preceding sub-species. Brittle. Sp. gr. 1.23 to 1.27. It occurs along with the preceding. It is found near Whitehaven, at Wigan, in Lancashire, Brosely, in Shropshire, near Sheffield; in Scotland, at Gilmerton and Muirkirk, where it is called parret-coal. It has been worked on the lathe into drinking vessels, snuff-boxes, &c.

3. *Foliated coal.* Its colour is velvet-black, sometimes with iridescent tarnish. Massive, and in lamellar concretions. Resinous or splendent lustre; uneven fracture, fragments approaching to trapezoidal. Soft-

er than cannel coal; between brittle and sectile. Easily broken. Sp. gr. 1.34 to 1.4. The Whitehaven variety consists, by Kirwan, of 57 carbon, 41.3 bitumen; and 1.7 ashes. It occurs in the coal formations of this and other countries. It is distinguished by its lamellar concretions, splendent lustre, and easy frangibility.

4. *Coarse coal.* Colour dark, grayish-black, inclining to brownish-black. Massive, and in granular concretions. Glistening lustre. Fracture imperfect scaly. Fragments indeterminate angular. Hardness as above. Easily frangible. Sp. gr. 1.454. It occurs in the German coal formations. To the above, Professor Jameson has added *soot-coal;* which has a dark grayish-black colour; is massive; with a dull semi-metallic lustre. Fracture uneven; sometimes earthy. Shining streak; soils; is soft, light, and easily frangible. It burns with a bituminous smell, cakes, and leaves a small quantity of ashes. It occurs along with slate-coal in West-Lothian and the Forth district; in Saxony and Silesia.

Species 3d. *Glance-coal,* of which the Professor gives two sub-species, pitch-coal, and glance-coal. 1. *Pitch-coal.* Colour velvet-black. Massive, or in plates and botrioidal branches, with a woody texture. Splendent and resinous. Fracture, large perfect conchoidal. Fragments sharp-edged and indeterminate angular; opaque; soft; streak brown coloured. Brittle. Does not soil. Sp. gr. 1.3. It burns with a greenish flame. It occurs along with brown coal in beds, in floetz, trap, and limestone rocks, and in bituminous shale. It is found in the Isles of Sky and Faroe; in Hessia, Bavaria, Bohemia, and Stiria. It is used for fuel, and for making vessels and snuff-boxes. It is called black amber in Prussia, and is cut into rosaries and necklaces. It is distinguished by its splendent lustre and conchoidal fracture. It was formerly called *jet,* from the river Gaga in Lesser Asia.

2. *Glance-coal;* of which we have four kinds, conchoidal, slaty, columnar, and fibrous. The conchoidal has an iron-black colour, inclining to brown, with sometimes a tempered steel-varnish. Massive and vesicular. Splendent, shining and imperfect metallic lustre. Fracture flat-conchoidal; fragments sharp-edged. Hardness as above. Brittle, and easily frangible. In thin pieces, it yields a ringing sound. It burns without flame or smell, and leaves a white coloured ash. Its constituents are 96.66 inflammable matter, 2 alumina, and 1.38 silica and iron. It occurs in beds in clay-slate, graywacke, and alum-slate; but it is more abundant in secondary rocks, as in coal and trap formations. It occurs in beds in the coal formations of Ayrshire, near Cumnock and Kilmarnock; in the coal district of the Forth; and in Staffordshire. It appears to pass into slaty glance-coal.

Slaty glance-coal. Colour iron-black. Massive. Lustre shining, and imperfect metallic. Principal fracture slaty; coarse fracture imperfect conchoidal. Fragments trapezoidal: Softer than conchoidal glance-coal. Easily frangible; between sectile and brittle. Sp. gr. 1.50. It burns without flame or odour. It consists, by Dolomieu, of 72.05 carbon, 13.19 silica, 3.29 alumina, 3.47 oxide of iron, and 8 loss. It occurs in beds or veins in different rocks. In Spain, in gneiss; in Switzerland, in mica-slate and clay-slate; in the trap rock of the Calton-hill, Edinburgh; in the coal formations of the Forth district. It is found also in the floetz districts of Westcraigs, in West Lothian, Dunfermline, Cumnock, Kilmarnock, and Arran; in Brecknock, Caermarthenshire, and Pembrokeshire, in England; and at Kilkenny, Ireland; and abundantly in the United States. In this country it is called blind coal.

Columnar glance-coal. Colour velvet-black and grayish-black. Massive, disseminated, and in prismatic concretions. Lustre glistening, and imperfect metallic. Fracture conchoidal. Fragments sharp-edged. Opaque. Brittle. Sp. gr. 1.4. It burns without flame or smoke. It forms a bed several feet thick in the coal-field of Sanquhar, in Dumfries-shire; at Saltcoats, in Ayrshire, it occurs in beds and in greenstone; in basaltic columnar rows near Cumnock, in Ayrshire.

Fibrous coal. Colour dark grayish-black. Massive, in thin layers, and in fibrous concretions. Lustre glimmering, or pearly. It soils strongly. It is soft, passing into friable. It burns without flame; but some varieties scarcely yield to the most intense heat. It is met with in the different coal-fields of Great Britain. Its fibrous concretions and silky lustre distinguish it from all the other kinds of coal.

It is not certain that this mineral is wood mineralized. Several of the varieties may be original carbonaceous matter, crystallized in fibrous concretions.—*Jameson.*

Parts.	*Charcoal.*	*Earth.*
100 Kilkenny coal contain	97.3	3.7
Anthracite, -	90.0	10.0
Ditto, - -	72.0	20.0
Ditto, - -	97.25	2.7
Coal of Notre Dame de Vaux,	78.5	20

The following table exhibits the results of Mr. Mushet's experiments on the carbonization and incineration of coals:

	Volatile matter.	*Char-coal.*	*Ashes.*	*Sp. gr. of coal.*	*Sp. gr. of coak.*
Welsh furnace coal, - - - -	8.50	88.068	3.432	1.337	1.
Alfreton do. do. - - - - -	45.50	52.456	2.044	1.235	less than 1.
Butterly do. do. - - - - -	42.83	52.882	4.288	1.264	1.1
Welsh stone do. - - - - -	8.00	89.700	2.300	1.368	1.39
Welsh slaty do. - - - - -	9.10	84.175	6.725	1.409	
Derbyshire cannel do. . - -	47.00	48.362	4.638	1.278	
Kilkenny coal, - - - - - -	4.25	92.877	2.873	1.602	1.657
Stone-coal found under basalt,	16.66	69.74	13.600		
Kilkenny slaty coal, - - -	13.00	80.475	6.525	1.445	
Scotch cannel-coal, - - - -	56.57	39.430	4.000		
Bonlavooneen do. - } -	13.80	82.960	3.240	1.436	1.596
Corgee coal, - - - } Irish.	9.10	87.491	3.409	1.403	1.656
Queen's County, No. 39. } -	10.30	86.560	3.140	1.403	1.622
Stone-wood, Giant's Causeway,	33.37	54.697	11.933	1.150	
Oak wood, - - - - - - - -	80.00	19.500	0.500		

It was remarked long ago by Macquer, that nitre detonates with no oily or inflammable matter, until such matter is reduced to coal, and then only in proportion to the carbonaceous matter it contains. Hence it occurred to Mr. Kirwan, that as coals appear in distillation to be for the most part merely compounds of carbon and bitumen, it should follow, that by the decomposition of nitre, the quantity of carbon in a given quantity of every species of coal may be discovered, and the proportion of bitumen inferred. This celebrated chemist accordingly projected on a certain portion of nitre in a state of fusion, successive fragments of various kinds of coal, till the deflagration ceased. Coal, when in *fine* powder, was thrown out of the crucible. The experiments seem to have been judiciously performed, and the results are therefore entitled to as much confidence as the method permits. Lavoisier and Kirwan state, that about 13 parts of dry wood-charcoal decompose 100 of nitre.

100 *parts.*	*Charcoal.*	*Bitumen.*	*Earth.*	*Sp. gr.*
Kilkenny coal,	97.3	0	3.7	1.526
Comp. cannel,	75.2	21 68 maltha	3.1	1.232
Swansey,	73.53	23.14 mixt.	3.33	1.357
Leitrim,	71.43	23.37 do.	5.20	1.351
Wigan,	61.73	36.7 do.	1.57	1.268
Newcastle,	58.00	40.0 do.	—	1.271
Whitehaven	57.0	41.3	1.7	1.257
Slaty-cannel,	47.62	32.52 mal.	20.0	1.426
Asphalt,	31.0	68.0 bitumen	—	1.117
Maltha,	8.0		—	2.07

100 parts of the best English coal give, of coak, - - 63. by Mr. Jars.
100 do. - - 73. Hielm.
100 do. Newcastle do. 58. Dr. Watson.

Mr. Kirwan says he copied the result, for Newcastle coal, from Dr. Watson.

The foliated or cubical coal, and slate coal, are chiefly used as fuel in private houses; the caking coals, for smithy forges; the slate coal, from its keeping open, answers best for giving great heats in a wind furnace, as in distillation on the great scale; and glance coal is used for drying grain and malt. The coals of South Wales contain less volatile matter than either the English or the Scotch; and hence, in equal weight, produce a double quantity of cast iron in smelting the ores of this metal. It is supposed that 3 parts of good Newcastle coals, are equivalent as fuel to 4 parts of good Scotch coals.

Werner has ascertained three distinct coal formations, without including the beds of coal found in sandstone and limestone formations. The first or oldest formation, he calls the independent coal formation, because the individual depositions of which it is composed, are independent of each other, and are not connected. The second is that which occurs in the newest floetz-trap formation; and the third occurs in alluvial land. Werner observes, that a fourth formation might be added, which would comprehend peat and other similar substances; so that we would have a beautiful and uninterrupted series, from the oldest formation to the peat, which is daily forming under the eye.

The *independent* formation contains exclusively coarse coal, foliated coal, cannel coal, slate coal, a kind of pitch coal, and slaty glance coal. The latter was first found in this formation in Arran, Dumfries-shire, Ayrshire, and at Westcraigs, by Professor Jameson. The formation in the newest floetz-trap contains distinct pitch coal, columnar coal, and conchoidal glance coal. The alluvial formation contains almost exclusively earth coal and bituminous wood. The first formation besides coal, contains three rocks which are peculiar to it; these are a conglomerate, which is more or less coarse-grained; a friable sandstone, which is always micaceous; and lastly, slate-clay. But besides these, there occur also beds of harder sandstone, marl, limestone, porphyritic stone, bituminous shale, clay-ironstone; and as discovered by Professor Jameson, greenstone, amygdaloid, and graphite. The slate-clay is well characterized, by the great variety of vegetable impressions of such plants as flourish in marshes and woods. The smaller plants and reeds occur in casts or impressions always laid in the direction of the strata; but the larger arborescent plants often stand erect, and their stems are filled with the substance of the superincumbent strata, which seems to show that these stems are in their original position. The leaves and stems resemble those of palms and ferns. The central, northern and western coal mines of England; the river coal districts of the Forth and the Clyde, and the Ayrshire, and in part the Dumfries-shire coals, belong to this formation, as well as the coals in the northern and western parts of France.

By far the most valuable and extensive beds of coal which have been found and wrought, are in Great Britain. The general form of our great independent coal-beds, is semi-circular, or semi-elliptical, being the segment of a great basin. The strata have a dip or declination to the horizon of from 1 in 5, to 1 in 20. They are rarely vertical, and seldom perfectly horizontal to any considerable extent. Slips and dislocations of the strata, however, derange more or less the general form of the basin.

Those who wish to understand the most improved modes of working coal mines, will be amply gratified by consulting, *A Report on the Leinster Coal District*, by Richard Griffith, Esq. Professor of Geology, and Mining Engineer to the Dublin Society. The author has given a most luminous view of Mr. Buddle's ingenious system of working and ventilating, in which from 7-8ths to 9-10ths of the whole coal may be raised; instead of only ½, which was the proportion obtained in the former modes. Mr. Griffith has since published some other reports, the whole constituting an invaluable body of mining information.*

* **Coal Gas.** When coal is subjected in close vessels to a red heat, it gives out a vast quantity of gas, which being collected and purified, is capable of affording a beautiful and steady light, in its slow combustion through small orifices. Dr. Clayton seems to have been the first who performed this experiment, with the view of artificial illumination, though its application to economical purposes was unaccountably neglected for about 60 years. At length Mr. Murdoch of the Soho Foundry, instituted a series of judicious experiments on the extraction of gas from ignited coal; and succeeded in establishing one of the most capital improvements which the arts of life have ever derived from philosophical research and sagacity.

In the year 1798, Mr. Murdoch, after several trials on a small scale five years before, constructed at the Foundry of Messrs. Bolton and Watt, an apparatus upon a large scale, which during many successive nights was applied to the lighting of their principal building; and various new methods were practised of washing and purifying the gas. In the year 1805, the cotton mill of Messrs. Philips and Lee, reckoned the most extensive in the kingdom, was partly lighted by gas under Mr. Murdoch's direction; and the light was soon extended over the whole manufactory. In the same year, I lighted up the large lecture-room of Anderson's Institution with coal-gas, generated in the laboratory; and continued the illumination every evening through that and the succeeding winter. Hence I was induced to pay particular attention to the theory and practice of its production and use.

If coal be put into a cold retort, and slowly exposed to heat, its bitumen is merely volatilized in the state of condensible tar. Little gas, and that of inferior illuminating power, is produced. This distillatory temperature may be estimated at about 600° to 700° F. If the retort be previously brought to a bright cherry-red heat, then the coals, the instant after their introduction, yield a copious supply of good gas, and a moderate quantity of tarry and ammoniacal vapour. But when the retort is heated to nearly a white incandescence, the part of the gas richest in light, is attenuated into one of inferior quality, as I have shown in detailing Berthollet's experiments on Carburetted Hydrogen. A pound of good cannel coal, properly treated in a small apparatus, will yield five cubic feet of gas, equivalent in illuminating power to a mould candle, six in the pound. See Candle.

On the great scale, however, 3½ cubic feet of good gas are all that should be expected from 1 pound of coal. A gas jet, which consumes half a cubic foot per hour, affords a steady light equal to that of the above candle.

According to Mr. Murdoch's statement, presented to the Royal Society, 2500 cubic feet of gas were generated in Mr. Lee's retort from 7 cwt.=784 lbs. of cannel coal. This is nearly 3⅕ cubic feet for every pound of coal, and indicates judicious management. The price of the best Wigan cannel is 13½d. per cwt. (22*s.* 6*d.* per ton) delivered at Mr. Lee's mill at Manchester; or about 8*s.* for the seven hundred weight. About ⅓ of the above quantity of of good common coal at 10*s.* per ton, is required for fuel to heat the retorts. Nearly ⅔ of the weight of the coal remains in the retort in the form of coak, which is sold on the spot at 1*s.* 4*d.* per cwt. The quantity of tar produced from each ton of cannel coal, is from 11 to 12 ale gallons.

The economical statement for one year is given by Mr. Murdoch thus:

Cost of 110 tons of cannel coal,	*l.*125
Ditto of 40 tons of common ditto,	20
	145
Deduct the value of 70 tons of coak,	93
The annual expenditure in coal, without allowing any thing for tar, is	52
And the interest of capital, and wear and tear of apparatus, - -	350
Making the total annual expense of gas apparatus about - -	600
That of candles to give the same light,	2000
If the comparison had been made upon an average of three hours per day, instead of two hours, (all the year round), then the cost from gas would be only - - - -	650
Ditto candles, - - - - -	3000

The peculiar softness and clearness of this light, with its almost unvarying intensity, soon brought it into great favour with the work-people. And its being free from the inconvenience and danger, resulting from the sparks and frequent snuffing of candles, is a circumstance of material importance, tending to diminish the hazard of fire, and lessening the high insurance premium on cotton-mills. The cost of the attendance upon candles would be fully more than upon the gas apparatus; and upon lamps greatly more, in such an establishment as Mr. Lee's. The preceding statements are of standard authority, far above the suspicion of empiricism or exaggeration, from which many subsequent statements by gas-book compilers are by no means exempt.

At the same manufactory, Dr. Henry has lately made some useful experiments on the quality of the gas disengaged from the same retort at different periods of the decomposition. I have united in the following table, the chief part of his results. He collected in a bladder the gas, as it issued from an orifice in the pipe, between the retorts and the tar pit; and purified it afterwards by agitation in contact of quicklime and water. Ten cwt. or 1120 lbs. of coal were contained in the retorts.

	Hours from commencement.	*100 measures of impure gas contain,*		*100 measures of purified gas contain,*			*100 measures of purified gas*		*100 combustible gas, exclusive of azote,*	
		Sulph. hydr.	*Carb. acid.*	*Olef.*	*Other infl. gases.*	*Azote*	*Consume oxyg.*	*Give car. ac.*	*Take oxygen*	*Carb. acid.*
Wigan cannel.	½	0½	5½	16	64	20	180	94	225	118
	1	3	3½	18	77¼	4¾	210	112	220	117
	3	2½	2½	15	80	5	200	108	210	114
	5	2½	2½	13	72	15	176	94	206	108
	7	2	2½	9	76	15	170	83	200	98
	9	0½	2½	8	77	15	150	73	176	85
	10½	0	2	6	74	20	120	54	150	70
	12	0	0½	4	76	20	82	36	103	45
Common coal from Clifton.	1	3	3	10	90	0	164	91	164	91
	3	2	2	9	91	0	168	93	168	93
	5	3	2	6	94	0	132	70	132	70
	7	1	3	5	80	15	120	64	140	75
	9	1	2½	2	89	9	112	60	123	66
	11½	1	1	0	85	15	90	43	106	50

Dr. Henry conceives *that* gas to have the greatest illuminating power, which, in a given volume, consumes the largest quantity of oxygen; and that hence the gas of cannel coal is one-third better, than the gas from common coal. 3500 cubic feet of gas were collected from 1120 pounds of the cannel coal; and only 3000 from the same weight of the Clifton coal.

From the preceding table, we see also that the gas which issues at the third hour contains, in 100 parts, of sulphuretted hydrogen and carbonic acid, each 2½, of azote 4¾, olefiant gas 14¼, and of other inflammable gases 76 parts.

A cubic foot of carbonic acid weighs 800 gr. A cubic foot of sulphuretted hydrogen weighs 620. The first takes about 1026 gr. of lime for its saturation; the second about 1070; and hence 1050, the quantity assigned by Dr. Henry for either, is sufficiently exact. 100 cubic feet of the above impure gas, containing 5 cubic feet of these two gases, will require at least 2100 grains of lime, or about 5 oz. avoirdupois for their complete condensation.

The proportion employed by Mr. Lee, is 5 pounds of fresh burned lime to 200 cubic feet of gas. The lime, after being slaked, is sifted, and mixed with a cubic foot (7.48 wine gallons) of water. This quantity of cream of lime, is adequate to the ordinary purification of the gas. Yet it will still slightly darken a card, coated with moistened white lead. A second exposure to lime makes it absolutely pure.

Measures.	*Oxygen.*	*Carb. acid.*
100 crude gas, consume	190	give 108
100 gas, once washed,	175	100
100 do. twice washed,	175	100

What is separated by the first washing is probably vapour of bitumen or petroleum, which would injure the pipes by its deposition, more than it would profit, by any increased quantity of light. Though we thus see that the second washing in the above experiment condensed none of the olefiant gas, it is prudent not to use unnecessary agitation in a large body of water.

The carbonate of lead precipitated from a cold solution of the acetate, by carbonate of ammonia, washed with water, and mixed with a little of that liquid into the consistence of cream, is well adapted to the separation of sulphuretted hydrogen from coal gas. The carbonic acid may then be withdrawn from the residuary gas, by a little water of potash. We must now determine the azote present, which is easily done by firing a volume of this gas with thrice its volume of pure oxygen. What remains after agitation with water of potash, is a mixture of azote and oxygen. Explode it with hydrogen; one-third of the diminution of volume shows the oxygen; the rest is azote. We have now to eliminate three quantities, viz. the volume of olefiant gas, that of common carburetted hydrogen, and that of carbonic oxide. Mr. Faraday has proved that chlorine acts pretty speedily on the second species of carburetted hydrogen, and therefore it cannot be employed with the view of condensing merely the first species. In contact with moisture, chlorine acts also rapidly on carbonic oxide, giving birth to muriatic and carbonic acids. If we be therefore deprived of all known means of *chemical* elimination, we shall find a ready and successful resource in the doctrines of specific gravity. In any mixture of two solids, two liquids, or two gases, whose specific gravities are known, it is easy to infer from the specific gravity of the compound (when the mixture is effected without change of volume) the relative weights of the two constituents. Thus if we apply to an alloy of gold and zinc, the old problem of Archimedes, we shall determine exactly the proportion of each metal present, because the volume of the alloy is very nearly the sum of the volumes of its ingredients. I have long applied this problem to gaseous mixtures, and found it a very convenient means of verification on many occasions, particularly in examining the nature of the residuary air in the lungs of the galvanized criminal, of which an account is given in the 12th Number of the Journal of Science.

Problem.—*In* 100 *measures of mixed gases, consisting, for example, of olefiant gas, carbonic oxide, and subcarburetted hydrogen, in unknown proportions, to determine the quantity of each.* The first step is to find the quantity of the two denser gases, which have the same specific gravity = 0.9720.

Rule.—Multiply by 100, the difference between the specific gravity of the mixture, and that of the lighter gas. Divide that number, by the sum of the differences of the sp. gr. of the mixture, and that of the denser and lighter gas; the quotient is the *per-centage* of the denser. *See Gregory's Mechanics*, vol. 1. p. 364.

Example.—A mixture of olefiant gas, carbonic oxide, and subcarburetted hydrogen, has a sp. gr. of 0.638.

What is the proportion *per cent* of the first two?

Sp. gr. of subcarb. hydrogen, is 0.555; 0.638—0.555 = 0.083 ∴ 100 × 0.083 = 8.3.

$$\begin{array}{l} 0.972 \\ 0\,638 \\ 0.555 \end{array} \begin{array}{l} \text{difference } 0.332 \\ \text{difference } 0.083 \end{array} \text{ sum } = 0.415$$

And $\frac{8\cdot3}{0\cdot415} = 20$ = volume of the two heavier gases; and therefore there are 80 of the lighter gas. Hence, having fired the whole with oxygen, we must allow 160 of oxygen, for saturating the 80 measures of the subcarburetted hydrogen. Then let us suppose 35 cubic inches more oxygen to have been consumed. We know that the saturating power of olefiant gas, and of carbonic oxide with oxygen, is in the ratio of 3 to 0.5. Therefore, the quantity of olef. gas =

$$\frac{35-(20\times0.5)}{3-0.5} = \frac{25}{2.5} = 10 \text{ measures.}$$

We see now, that a gas of sp. gr. 0.638 consists of

0.8	measures	subcarb. hydrogen	=	0.444
0.1	do.	olefiant gas	=	0.097
0.1	po.	carb. oxide	=	0.097
				0.638

For further details see Gas.

Dr. Henry gives, at the end of his experiments, (Manchester Memoirs, vol. iii. second series), some hypothetical representations of the constitution of coal gases, in one of which he assigns,

2 of carburetted hydrogen,
2 of carbonic oxide,
and 15 of pure hydrogen, in $18\frac{2}{3}$ measures.

With mixtures of *three* gaseous bodies, the problem of eliminating the proportion of the constituents, by explosion with oxygen, becomes complex, and several hypothetical proportions may be proposed. But I can hardly imagine, that pure hydrogen should be disengaged from ignited coal. There is no violation of the doctrine of multiple proportions, in conceiving a compound to exist in which three or more atoms of hydrogen may be united with one of carbon. Berthollet's experiments render this view highly probable. If the above hypothetical numbers were altered to 1.6; 2.4; and 15; their accordance with Dr. Henry's experiments would be improved. Now, this is a considerable latitude of adjustment.

The principles laid down at the commencement of this article show, that the more uniformly the coal undergoes igneous decomposition, the richer is the gas. The retorts, if cylindrical, should not exceed, therefore, 12 or 14 inches diameter, and six or seven feet in length. Compressed cylinders, whose length is $4\frac{1}{2}$ feet, breadth 2 feet, and inside vertical diameter about 10 inches, have been found to answer well at Glasgow. The cast iron of which they are composed, must be screened from the direct impulse of the fire, by a case of fire-brick.

On the maximum quantity of gas procurable from coal, it is difficult to acquire satisfactory information, at the great gas establishments. Exaggeration seems to be the prevailing foible. Mr. Accum gives the following tables, as the maximum results of his own experiments, made at the Royal Mint gas-works;—

		Cubic feet of gas.
Scotch cannel coal,	- -	19.890
Lancashire Wigan cannel,	-	19.608
Yorkshire cannel, Wakefield,	-	18.860
Staffordshire coal,	1st variety, -	9.748
By experim. at Birmingham gas works,	2d do. -	10.223
	3d do. -	10.866
	4th do. -	9.796
Gloucester coal,	High Delph, -	16.584
Do.	Low Delph, -	12.852
Do.	Middle Delph, -	12.096
Newcastle coal,	Hartley, -	16.120
	Cowper's High Main,	15.876
	Tanfield Moor, -	16.920
	Pontops, -	15.112

The following varieties of coal, according to Mr. Accum, contain a less quantity of bitumen, and a larger quantity of carbon than the preceding. They soften, swell, and cake on the fire, and are well calculated for the production of coal gas:—

One chaldron produces,

Newcastle coal,	Russel's Wall's-end,	16.876
	Bewicke and Crastor's Wall's-end,	16.897
	Heaton Main, -	15.876
	Bleyth, - -	12.096
	Eden Main, -	9.600
	Primrose Main, -	8.348

Concerning the *duration* of the decomposition of a retort-charge of one cwt., various opinions are maintained. Mr. Peckston's experiments at the gas light and coak company's works, Westminster station, seem to prove, that decided advantages attend the continuance of the process for eight hours, in preference to six, or any shorter period. The average product of gas, from one chaldron of Newcastle coals, at six hours' charges, he states at 8,300 cubic feet, and at those of eight hours, at 10,000. On 76 retorts, worked for a week at the latter rate, he gives a statement to prove, that there is a saving of 77*l.* 18*s.* above the former rate of working. Two men, one by day, and one by night, can attend nine or ten retorts, at eight hours charges, of 100 pounds of coal each.

Scotch cannel yields its gas most readily, or - - - - -	1.00
Newcastle coal, - - -	1.04
Gloucester Low Delph, - -	1.08
Newcastle. Brown's Wall's-end, -	1.18
Warwickshire, - - -	1.65

Hence, the latter kinds afford good gas, long after the former are exhausted.

The following table by Mr. Peckston exhibits the ratio at which the gas is evolved from Bewicke and Crastor's Wall's-end coal, when the retorts are worked at eight hours' charges:—

	Cubic feet.	*Sum.*
During the 1st hour are generated,	2000	
2d,	1495	3495
3d,	1387	4882
4th,	1279	6161
5th,	1189	7350
6th,	991	8341
7th,	884	9225
8th,	775	10000

We have already explained the principles of purifying gas by milk of lime. But previous to its agitation with that liquid, it should be made to traverse a series of refrigeratory pipes submersed under cold water. A vast variety of apparatus, some very ingenious, but many absurd, have been contrived within these few years, for exposing gas to lime in the liquid or dry state. Mr. Accum and Mr. Peckston have been at much pains in describing several of them. The gas holder is now generally preferred of a cylindrical shape, like an immense drum, open at bottom; and flat, or slightly conical at top. The diameter is from

33 to 45 feet in the large establishments, and the height from 18 to 24. The average capacity is from 15000 to 20000 cubic feet. It is suspended in a tank of water by a strong iron chain fixed to the centre of its summit, which passing round a pulley, bears the counter-weight. When totally immersed in water, the sheet-iron, of which the gas holder is composed, loses hydrostatically about $\frac{2}{15}$ of its weight; or if equipoised when immersed, it becomes $\frac{2}{15}$ heavier when in air, *minus* the buoyancy of the included gas. The mean sp. gr. of well purified coal-gas by Dr. Henry's late experiments may be computed at 0.676, to air called 1.000; or in round numbers, its density may be reckoned two-thirds of that of air. One cubic foot of air weighs 527 gr., one cubic foot of gas weighs 351 gr.; the difference is 176 gr. Hence, 40 cubic feet have a buoyancy of one pound avoirdupois.

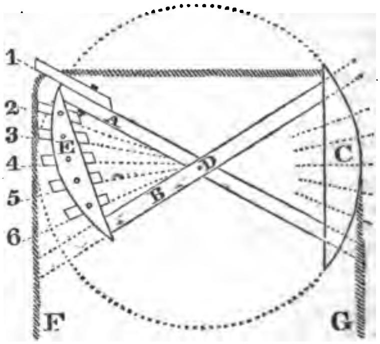
The hydrostatic compensation is obtained by making the weight of that length of the suspending chain which is between the top of the immersed gasometer and the tangential point of the pulley-wheel, equal to *one-fifteenth* the weight of the gasometer in pounds, minus its capacity in cubic feet, divided by twice 40, or 80. Thus, if its weight be 4 tons, or 8960 lbs.; and its capacity 15000 cubic feet, a length of chain equal to the height of the gasometer, or to its vertical play, should weigh 597 lbs. without allowing for buoyancy. In this case, the gasometer, when out of water, would have the buoyancy of that liquid, replaced by the passage of these 597 lbs. to the opposite side of the wheel-pulley, so that twice that weight = 1194 lbs. would then be added to the constant counterpoise. When the gasometer again sinks, and loses its weight by the displacement of the liquid, successive links of the chain come over above it, augmenting its weight, and diminishing that of the counterpoise, by a twofold operation, as in taking a weight out of one scale, and putting it in the other.

But we must now introduce the correction for the buoyancy of the combustible gas. In ordinary cases, we must regard it as holding a portion of petroleum vapour diffused through it, and cannot fairly estimate its specific gravity at less than 0.750; whence nearly 50 cubic feet have a buoyancy of one pound over the same bulk of atmospheric air. If we divide 15000 by 50, the quotient = 300 is the double of what must be deducted in pounds weight from the hydrostatic compensation. Thus, 597 — 150 = 447, is the weight of the above portion of chain. When the gasometer attains its greatest elevation, these 447 lbs. hang on the opposite side of the wheel, constituting an increased counterpoise of twice 447 = 894, to which, if we add the total buoyancy of the included gas = 300 lbs. we have the sum 1194, equal to the total increase of the weight of the iron vessel on its suspension in air.

†The following plan for suspending gasometers was devised by me several years ago, and published in the Analeclic Magazine of this city for May 1817.

"Account of an improved mode of suspending gasometers; by Dr. Hare.

"It is well known to all who are conversant in gas light apparatus, that no mode has been heretofore devised to render gasometers accurately equiponderant at all points of their immersion in the water; a circumstance so indispensable to their action. The mode adopted in the large London establishments, and which appears to be the most approved, is that of the gasometer chain. This is costly; difficult to execute well, and not susceptible of correction, when erroneously proportioned to the desired effect; especially after the apparatus is in operation. From all these faults, the method of suspension on a beam, like that in the following cut, is entirely free. In practice it has answered perfectly: and, when we have described the mode of constructing such a beam, we think the rationale of its operation will become self-evident.



Find (by trial, if possible; if not, by calculation) the weight of the gasometer when sunk so low, as that the top will be as near as possible to the water, without touching it. In the same way find the weight of the gasometer at the highest point of immersion, to which it is to rise, when in use. Then, as the weight in the last case, is to the weight in the first; so let the length of the arm A, be to the length of the arm B. From the centre D, with the radius A, describe a circle; on which set off an arch C, equal to the whole height through which the gasometer is to move. Divide this into as many parts as there are spaces in it, equal each to one-sixth of the radius or length of arm A. Through the points thus found, draw as many diameters; which will, of course, form a corresponding number of radii and divisions, on the opposite side of the circle. Divide the difference between the length of A and B, by the sum of these divisions: and let the quotient be *q*. From the centre D towards the side E, on radius 2, set off a distance equal to the length of the arm A, less the quotient or *q*. On radius 3, set off a distance equal to A, less 2 *q*, or twice the quotient; and so set off distances on each of the radii; the last being always less than the preceding, by the value of *q*. A curve line bounding the distances thus found, will be that of the arch head E. The beam being supported on a gudgeon at D, let the gasometer be appended at G; and let a weight be appended at F, adequate to balance it at any one point of immersion. This same weight will balance it at all other points of its immersion—provided the quantity of water displaced by equal sections of the gasometer be equal. But as the weights on which A and B were predicated, may not be quite correct, and as, in the construction of large vessels, equability of thickness and shape cannot be sufficiently attained—the consequent irregular buoyancy is compensated by causing the weight to hang nearer to, or farther from the centre, at any of the points taken in making the curve. This object is accomplished by varying the sliders seen opposite to the figures 1, 2, 3, 4, 5, 6. When they are properly adjusted, they are made firm by the screws of which the heads are visible in the diagram.

The drawing is of a beam twelve feet in length; and of course the length of the arm A is six feet—that of B, four feet—their difference two feet; which divided by 6, the number of points taken in making the curve E, gives four inches for the quotient *q*. Hence the distance on radius 2, was five feet eight inches—on radius 3, five feet four inches—on radius 4, five feet—on radius 5, four feet eight inches—on radius 6, four feet four inches—and lastly four feet.

The iron gudgeon, where it enters the beam, is square. The projecting parts are turned true, and should be bedded in brass or steel dies; placed, of course, on a competent frame. The sixth part of a revolution of the portions of the gudgeon thus supported, is the only source of friction to which this beam is subject during the whole period of the descent of the gasometer;—which, in large ones, does not ordinarily take place in less than six hours."†

The principles of the distribution of gas are exhibited in the following table, given by Mr. Peckston. The gas holder is worked at a pressure of one vertical inch of water, and each argand burner consumes five cubic feet per hour.

Inter. diamr of pipe in inches.	*Cubic feet passing per hour.*	*Burners supplied.*
$\frac{2}{8}$	20	4
$\frac{3}{8}$	50	10
$\frac{4}{8}$	90	18
$\frac{5}{8}$	160	32
$\frac{6}{8}$	250	50
$\frac{7}{8}$	380	76
1	500	100
2	2000	400
3	4500	900
4	8000	1600
5	12500	2500
6	18000	3600
7	24500	4900
8	32000	6400
9	40500	8100
10	50000	10000
12	72000	14400
14	98000	19600
16	128000	25600
18	162000	32400

The following statement is given by Mr. Accum. An argand burner, which measures in the upper rim half an inch in diameter between the holes from which the gas issues, when furnished with five apertures 1-25th part of an inch diameter, consumes two cubic feet of gas in an hour, when the gas flame is one and a half inch high. The illuminating power of this burner is equal to three tallow candles eight in the pound.

An argand burner three-fourths of an inch in diameter as above, and perforated with holes 1-30th of an inch diameter (what number? probably 15) consumes three cubic feet of gas in an hour when the flame is 2½ inches high, giving the light of four candles eight to the pound. And an argand burner seven-eighths of an inch diameter as above, perforated with 18 holes 1-32d of an inch diameter, consumes, when the flame is three inches high, four cubic feet of gas per hour, producing the light of six tallow candles eight to the pound. Increased length of flame makes imperfect combustion, and diminished intensity of light. And if the holes be made larger than 1-25th of an inch, the gas is incompletely burnt. The height of the glass chimney should never be less than five inches.

The argand burner called No. 4, when burnt in shops from sunset till nine o'clock, is charged three pounds a-year. The diameter of its circle of holes is five-eighths of an inch, and of each hole 1-32d of an inch. It is drilled with 12 holes, 5-32ds of an inch from the centre of one to the centre of another. Height of this burner 1⅞ inches.

No. 6, argand burner. 15 apertures of 1-32d of an inch; diameter of their circle three-fourths of an inch; height of burner two inches; charge per ann. four guineas.

According to Mr. Accum, one gas lamp, consuming 4 cubic feet of gas in an hour, if situated 20 feet distant from the main, which supplies the gas, requires a tube not less than a quarter of an inch in the bore; 2 lamps, 3 feet distance, require a tube three-eighths of an inch; 3 lamps, 30 feet distance, require a tube three-eighths: 4 lamps at 40 feet, one-half inch bore; 10 lamps, at 100 feet distance, require a tube three-fourths of an inch; and 20, 150 feet distant, 1¼ inch bore.

We have seen that the average product in London from 1 pound of coal in 8 hours, is 3½ cubic feet. In the Glasgow coal gas establishment, which is conducted by engineers skilled in the principles of chemistry and mechanics, fully 4 cubic feet of gas are extracted from every pound of coal of the splent kind in 4 hour charges, from retorts containing each 120 lbs; which is about two-thirds of their capacity. The decomposing heat is much the same as that used in London, but the retorts are compressed cylinders, a little concave below. Hence in 8 hours, fully double the London quantity of gas, is obtained from a retort in Glasgow.

An ingenious pupil of mine, lately employed by a projected gas company in Glasgow to visit the principal factories of gas in England, made a series of accurate experiments on its illuminating quality in the different towns. For this purpose, he carried along with him a mould candle, six in the pound, and a single-jet gas-nozzle. By attaching this to a gas-pipe, and producing a flame of determinate length, (three inches), he could then, by the method of shadows, compare the flame of the gas with that of his candle, and ascertain their relative proportions of light. He found that the average illuminating power of the gas in the English establishments, was to that of the Glasgow company, as four to five; the worst being so low as three to five, and the best as five to six. If we therefore multiply this ratio, into the double product of gas obtained in the Glasgow gas-work, we shall have the proportion of light generated here, and in London, from an equal sized retort, in an equal time, as 100 to 40. This result merits entire confidence. In the sequel of the article Light, in this Dictionary, instructions will be given how to calculate the relative illuminating powers of different flames.

When the tar is passed through ignited iron pipes, it yields from 10 to 15 cubic feet of gas per pound. The deposite of refractory asphaltum, however, is very apt to obstruct the pipes; and the light afforded is perhaps of inferior quality. Hence tar is decomposed in very few establishments.

The film of petroleum, which floats on the water of the gasometer tank, and that procured from the tar by distillation, have been used instead of oil for street-lamps. The lamp fountain is kept on the outside of the glass lantern, and the flame is made small, to prevent an explosion of the vaporized naphtha.

1430 lbs. of tar by boiling yield 9 cwt. of good pitch. From a chaldron of Newcastle coal about 200 lbs. of ammoniacal liquor are obtained; a solution chiefly of the carbonate and sulphate. The strongest liquor comes from the caking coal. A gallon, or 8½ lbs. usually requires for saturation from fifteen to sixteen ounces of oil of vitriol, sp. gr. 1.84. To obtain subcarbonate of ammonia, 125 lbs. of calcined gypsum in fine powder are added to 108 gallons of the ammoniacal liquor. The mixture is stirred, and the cask containing it, is then closed for three or four hours. Sixteen ounces of sulphuric acid are now mixed in; and the whole allowed to remain at rest for four or six hours. The supernatant sulphate of ammonia is next evaporated till it crystallize. One hundred weight of the dry crystals is mixed with one-fourth of their weight of dry chalk in powder, and sublimed from a cylindrical iron retort into a barrel-shaped receiver of lead. A charge of 120 lbs. of the mixture, is usually decomposed in the course of twenty-four hours. One hundered weight of dry sulphate of ammonia, is said to produce from sixty to sixty-five pounds of solid subcarbonate of ammonia. If the sulphate of ammonia, mixed with common salt, is exposed to a subliming heat, sal ammoniac is obtained. For oil gas, see Oil.*

Coating, or Lorication. Chaptal recommends a soft mixture of marly earth, first soaked in water, and then kneaded with fresh horse-dung, as a very excellent coating.

The valuable method used by Mr. Willis of Wapping to secure or repair his retorts used in the distillation of phosphorus, deserves to be mentioned here. The retorts are smeared with a solution of borax, to which some slaked lime has been added, and when dry, they are again smeared with a thin paste of slaked lime and linseed oil. This paste being made somewhat thicker, is applied with success, during the distillation, to mend such retorts as crack by the fire.

*Cobalt. A brittle, somewhat soft, but difficultly fusible metal, of a reddish-gray colour, of little lustre, and a sp. gr. of 8.6. Its melting point is said to be 130° Wedgewood. It is generally associated in its ores with nickel, arsenic, iron, and copper; and the cobalt of commerce usually contains a proportion of these metals. To separate them, calcine with 4 parts of nitre, and wash away, with hot water, the soluble arsenite of potash. Dissolve the residuum in dilute nitric acid, and immerse a plate of iron in the solution, to precipitate the copper. Filter the liquid and evaporate to dryness. Digest the mass with water of ammonia, which will dissolve only the oxides of nickel and cobalt. Having expelled the excess of alkali by a gentle heat from the clear ammoniacal solution, add cautiously water of potash, which will precipitate the oxide of nickel. Filter immediately, and boil the liquid, which will throw down the pure oxide of cobalt. It is reduced to the metallic state by ignition in contact with lampblack and oil. Mr. Laugier treats the above ammoniacal solution with oxalic acid. He then redissolves the precipitated oxalates of nickel and cobalt in concentrated water of ammonia, and exposes the solution to the air. As the ammonia exhales, oxalate of nickel, mixed with ammonia, is deposited. The nickel is entirely separated from the liquid by repeated crystallizations. There remains a combination of oxalate of cobalt and ammonia, which is easily reduced by charcoal to the metallic state. The small quantity of cobalt remaining in the precipitated salt of nickel, is separated by digestion in water of ammonia.

Cobalt is susceptible of magnetism, but in a lower degree than steel and nickel.

Oxygen combines with cobalt in two proportions; forming the dark blue protoxide, and the black deutoxide. The first dissolves in acids without effervescence. It is procured by igniting gently in a retort the oxide precipitated by potash, from the nitric solution. Proust says, the first oxide consists of 100 metal + 19.8 oxygen; and Rothoff makes the composition of the deutoxide 100 + 36.77. If we call the first 18.5 and the second 37; then the prime equivalent of cobalt will be 5.4; and the two oxides will consist of

Protox.	Cobalt,	5.4	100	84.38
	Oxygen,	1.0	18.5	15.62
				100.00

Deutox.	Cobalt,	5.4	100	73
	Oxygen,	2.0	37	27
				100

The precipitated oxide of cobalt, washed and gently heated in contact with air, passes into the state of black peroxide.

When cobalt is heated in chlorine, it takes fire, and forms the chloride. The iodide, phosphuret, and sulphuret of this metal have not been much examined.

The salts of cobalt are interesting from the remarkable changes of colour which they can exhibit.

Their solution is red in the neutral state, but green, with a slight excess of acid; the alkalis occasion a blue coloured precipitate from the salts of pure cobalt, but reddish-brown when arsenic acid is present; sulphuretted hydrogen produces no precipitate, but hydrosulphurets throw down a black powder, soluble in excess of the precipitant; tincture of galls gives a yellowish-white precipitate; oxalic acid throws down the red oxalate. Zinc does not precipitate this metal.

The sulphate is formed by boiling sulphuric acid on the metal, or by dissolving the oxide in the acid. By evaporation, the salt may be obtained in acicular rhomboidal prisms of a reddish colour. These are insoluble in alcohol, but soluble in 24 parts of water. It consists, by the analysis of Bucholz, of;

	Exper't.			*Theory.*
Acid,	26	or 1 prime	5.0	24.4
Protoxide,	30	1 do.	6.4	31.4
Water,	44	8 do.	9.	44.2
	100		20.4	

Dr. Thomson's hypothetical synthesis differs widely from the experimental, in consequence of his assuming 3.625 for an atom of the metal, and 4.625 for that of its oxide. He gives 28.57 acid + 26.43 protoxide + 45 water.

The nitrate forms prismatic red deliquescent crystals. It is decomposable by gentle ignition. The muriate is easily formed by dissolving the oxide in muriatic acid. The neutral solution is blue when concentrated, and red when diluted; but a slight excess of acid makes it green. According to Klaproth, a solution of the pure muriate forms a sympathetic ink, whose traces become blue when the paper is heated; but if the salt be contaminated with iron, the traces become green. I find that the addition of a little nitrate of copper to the solution forms a sympathetic ink, which by heat gives a rich greenish-yellow colour. When a small quantity of muriate of soda, of magnesia, or of lime is added to the ink, its traces disappear very speedily on removal from the fire; showing that the vivid green, blue, or yellow colour, is owing to the concentration of the saline traces by heat, and their disappearance, to the reabsorption of moisture. At a red heat, the greater part of the muriate sublimes in a gray coloured chloride. The acetate forms a sympathetic ink, whose traces being heated, become of a dull blue colour. The arseniate of cobalt is found native in a fine red efflorescence, and in crystals. See ORES of Cobalt. A cream-tartrate o cobalt may be obtained in large rhomboidal crystals, by adding the tartrate of potash to cobaltic solutions, and slow evaporation. An ammonia-nitrate of cobalt may be formed in red cubical crystals, by adding ammonia in excess to the nitric solution, and evaporating at a very gentle heat. They have a urinous taste, and are permanent in the air. The red oxalate is soluble in an excess of oxalic acid, and hence neutral oxalate of potash is the proper reagent for precipitating cobalt. The phosphate may be formed by double decomposition. It is an insoluble purple powder, which, heated along with eight parts of gelatinous alumina, produces a beautiful blue pigment, a substitute for ultra-marine. The colouring power of oxide of cobalt on vitrifiable mixtures, is greater perhaps than that of any other metal. One grain gives a full blue to 240 grains of glass. Zaffre is a mixture of flint powder and an impure oxide of cobalt, prepared by calcination of the ores. Smalt and azure blue are merely cobaltic glass in fine powder. See Glass.*

* **Cobalus.** The demon of mines, which obstructed and destroyed the miners. The church service of Germany formerly contained a form of prayer for the expulsion of the fiend. The ores of the preceding metal being at first mysterious and intractable, were nicknamed cobalt.*

* **Coccolite.** A mineral of green colour of various shades, which occurs, massive; in loosely aggregated concretions; and crystallized in six-sided prisms, with two opposite acute lateral edges, and bevelled on the extremities, with the bevelled planes set on the acute lateral edges; or in four-sided prisms. The crystals are generally rounded on the angles and edges. The internal lustre is vitreous. Cleavage, double oblique angular. Fracture uneven. Translucent on the edges. It scratches apatite, but not feldspar. Is brittle. Sp. gr. 3.3. It fuses with difficulty before the blowpipe. Its constituents are silica 50, lime 24, magnesia 10, alumina 1.5, oxide of iron 7, oxide of manganese 3, loss 4.5. *Vauquelin.*

It occurs along with granular limestone, garnet and magnetic ironstone, in beds subordinate to the trap formation. It is found at Arendal in Norway, Nericke in Sweden, Barkas in Findland, the Hartz, Lower Saxony, and Spain.*

Cochineal was at first supposed to be a grain, which name it still retains by way of eminence among dyers, but naturalists soon discovered that it was an insect. It is brought to us from Mexico, where the insect lives upon different species of the opuntia.

Fine cochineal, which has been well dried and properly kept, ought to be of a gray colour inclining to purple. The gray is owing to a powder which covers it naturally, a part of which it still retains: the purple tinge proceeds from the colour extracted by the water in which it has been killed. Cochineal will keep a long time in a dry place. Hellot says, that he tried some, one hundred and thirty years old, and found it produced the same effect as new.

* MM. Pelletier and Caventou have lately found that the very remarkable colouring matter which composes the principal part of cochineal, is mixed with a peculiar animal matter, a fat like common fat, and with different salts. The fat having been separated by ether, and the residuum treated with boiling alcohol, they allowed the alcohol to cool as they gently evaporated it, and by this means they obtained the colouring matter; but still mixed with a little fat and animal matter. These were separated from it, by again dissolving it in cold alcohol, which left the animal matter untouched, and by mixing the solution with ether, and thus precipitating the colouring matter in a state of great purity, which they have called *carminium.* It melts at 122° Fahr. becomes puffy, and is decomposed, but does not yield ammonia. It is very soluble in water, slightly in alcohol, and not at all in ether, unless by the intermediation of fat. Acids change it from crimson, first to bright red, and then to yellow; alkalis, and, generally speaking, all protoxides turn it to violet; alumina takes it from water. Lake is composed of carminium and alumina. Carmine is a triple compound of an animal matter, *carminium,* and an acid which enlivens the colour. The action of muriatic acid in changing the crimson colour of cochineal into a fine scarlet, is similar.

Dr. John calls the red colouring matter cochenilin. He says, the insect consists of

Cochenilin,	50.0
Jelly,	10.5
Waxy fat,	10.0
Gelatinous mucus,	14.0
Shining matter,	14.0
Salts,	1.5
	100.0

Coffee. The seeds of the *coffea arabica* are contained in an oval kernel, enclosed in a pulpy berry, somewhat like a cherry. The ripe fruit is allowed slightly to ferment, by which the pulp is more easily detached from the seeds. These are afterwards washed, carefully dried in the sun, and freed from adhering membranes by winnowing. Besides the peculiar bitter principle, which we have described under the name caffein, coffee contains several other vegetable products. According to Cadet, 64 parts of raw coffee consist of 8 gum, 1 resin, 1 extractive and bitter principle, 3.5 gallic acid, 0.14 albumen, 43.5 fibrous insoluble matter, and 6.86 loss. Hermann found in 1920 grains of

	Levant Coffee.	*Mart. Coffee.*
Resin,	74	68
Extractive,	320	310
Gum,	130	144
Fibrous matter,	1335	1386
Loss,	61	12
	1920	1920

The nature of the volatile fragrant principle, developed in coffee by roasting, has not been ascertained. The Dutch in Surinam improve the flavour of their coffee by suspending bags of it, for two years, in a dry atmosphere. They never use new coffee.*

Coffee is diuretic, sedative, and a corrector of opium. It should be given as medicine in a strong infusion, and is best cold. In spasmodic asthma it has been particularly serviceable; and it has been recommended in gangrene of the extremities arising from hard drinking.

* Cohesion, or attraction of cohesion, is that power by which the particles of bodies are held together. The absolute cohesion of solids is measured by the force necessary to pull them asunder. Heat is excited at the same time. At the iron cable manufactory of Captain Brown, a cylindrical bar of iron, 1½ inch diameter, was drawn asunder by a force of 43 tons. Before the rupture, the bar lengthened about 5 inches, and the section of fracture was reduced nearly $\frac{3}{8}$ of an inch. About this part, a degree of heat was generated, which, according to Mr. Barlow of Woolwich, rendered it unpleasant, if not in a slight degree painful, to grasp the bar in the hand. The same thing is shown in a greater degree in wire-drawing. When the force is applied to compress the body, it becomes shorter in the direction of the force, which is called the *compression;* and the area of its section at right angles to the force, expands. The cohesion, calculated from the transverse strength, is as near, or perhaps nearer, the real cohesion, than that obtained by pulling the body asunder. The cohesive force of metals is much increased by wire-drawing, rolling, and hammering them. In the elaborate tables of cohesion drawn up by Mr. Thomas Tredgold, and published in the 50th vol. of Tilloch's Magazine, the specific cohesion of plate glass (a pretty uniform body) is denoted by unity.

The following table is the result of experiments by George Rennie, Jun. Esq. published in the first part of the Phil. Transactions for 1818.

Mr. Rennie found a cubical inch of the following bodies crushed by the following weights:

	lbs. av.
Elm,	1284
American pine,	1606
White deal,	1928
English oak,	3860
Ditto of five inches long, slipped with,	2572
Ditto of four inches, ditto,	5147
A prism of Portland stone, two inches long,	805
Ditto statuary marble,	3216
Craigleith stone,	8688

Cubes of 1½ inch.

	sp. gr.	
Chalk,	—	1127
Brick of a pale red colour,	2.085	1265
Roe-stone, Gloucestershire,	—	1449
Red brick, mean of two trials,	2.168	1817
Yellow face baked Hammersmith paviors, three times,	—	2254
Burnt ditto, mean of two trials,	—	3243
Stourbridge, or fine brick,	—	3864
Derby grit, a red friable sandstone,	2.316	7070
Derby grit from another quarry,	2.428	9776
Killaly white freestone, not stratified,	2.423	10264
Portland,	2.428	10284
Craigleith, white freestone,	2.452	12346
Yorkshire paving, with the strata,	2.507	12856
Ditto, against the strata,	2.507	12856
White statuary marble, not veined,	2.760	13632
Bramley-Fall sandstone, near Leeds, with strata,	2.506	13632
Ditto, against strata,	2.506	13632
Cornish granite,	2.662	14302
Dundee Sandstone, or breccia, two kinds,	2.530	14918
A two inch cube of Portland,	2.423	14918
Craigleith, with strata,	2.452	15560
Devonshire red marble, variegated,	—	16712
Compact limestone,	2.584	17354
Peterhead granite, hard close-grained,	—	18636
Black compact limestone, Limerick,	2.598	19924
Purbeck,	2.599	20610
Black Brabant marble,	2.697	20742
Very hard freestone,	2.528	21254
White Italian veined marble,	2.726	21783
Aberdeen granite, blue kind,	2.625	24556

Cubes of different metals of ¼th inch were crushed by the following weights.

Cast iron,	9773
Cast copper,	7318
Fine yellow brass,	10304
Wrought copper,	6440
Cast tin,	966
Cast lead,	483

Bars of different metals, six inches long, and a quarter of an inch square, were suspended by nippers, and broken by the following weights:

Cast iron, horizontal, - -	1166
Ditto, vertical, - - -	1218
Cast steel, previously tilted, -	8391
Blistered steel, reduced by the hammer,	8322
Shear steel ditto, - - -	7977
Swedish iron ditto, - -	4504
English iron ditto, - - -	3492
Hard gun metal, mean of two trials,	2273
Wrought copper, reduced by hammer, - - - - - -	2112
Cast copper, - - - - -	1192
Fine yellow brass, - - -	1123
Cast tin, - - - - - -	296
Cast lead, - - - - -	114

For the experiments on the twist of bars we must refer to the paper.

The strengths of Swedish and English iron do not bear the same proportion to each other in these experiments, that they do when we compare the trials of Count Sickingen with those made at Woolwich, of which an account was given in the *Annals of Philosophy*, vii. 320. From that comparison, the proportional strengths were as follows:

English iron, -	348.38
Swedish iron, -	549.25

But from Mr. Rennie's experiments, the proportional strengths are:

English iron, -	348.38
Swedish iron, -	449.34

A very material difference, which ought to be attended to.

The following Table contains a view of some former experiments, on the cohesive strengths or tenacities of bodies.

A wire $\frac{1}{10}$ inch of	zinc breaks with	26 pounds.	Mechenbroek.
Do.	lead	29½	Emerson.
Do.	tin	49¼	do.
Do.	copper	299¼	do.
Do.	brass	360	do.
Do.	silver	370	do.
Do.	iron	450	do.
Do.	gold	500	do.
A cylinder 1 inch	iron	63320	Rumford.

According to Sickingen, the relative cohesive strengths of the metals are as follows:

Gold,	150955
Silver,	190771
Platina,	262361
Copper,	304696
Soft iron,	362927
Hard iron,	559880

A wire of iron 0.078 or $\frac{1}{12.8}$ of an inch, will just support 549.25 pounds. Emerson's number for gold is excessively incorrect. In general, iron is about 4 times stronger than oak, and 6 times stronger than deal.*

* **Cohobation.** The continuous redistillation of the same liquid, from the same materials.*

Colcothar. The brown-red oxide of iron, which remains after the distillation of the acid from sulphate of iron: it is used for polishing glass and other substances by artists, who call it crocus, or crocus martis.

Cold. The privation of heat. See Caloric, Congelation, and Temperature.

Colophony. Colophony, or black resin, is the resinous residuum after the distillation of the light oil, and thick dark reddish balsam, from turpentine.

* **Columbium.** If the oxide of columbium described under Acid (Columbic) be mixed with charcoal, and exposed to a violent heat in a charcoal crucible, the metal columbium will be obtained. It has a dark gray colour; and when newly abraded, the lustre nearly of iron. Its sp. gr., when in agglutinated particles, was found by Dr. Wollaston to be 5.61 These metallic grains scratch glass, and are easy pulverized. Neither nitric, muriatic, nor nitro-muriatic acid produces any change in this metal, though digested on it for several days. It has been alloyed with iron and tungsten. See Acid (Columbic.)*

* **Colchicum Autumnale.** A medicinal plant, the vinous infusion of whose root has been shown by Sir E. Home to possess specific powers of alleviating gout, similar to those of the empirical preparation called *Eau medicinale D'Husson.* The sediment of the infusion ought to be removed by filtration, as it occasions gripes, sickness, and vomiting.*

* **Colophonite.** A mineral of a blackish, or yellowish-brown, or orange-red colour; of a resino-adamantine lustre; and conchoidal fracture. Its sp. gr. is 4.0. It consists of silica 35, alumina 13.5, lime 29.0, magnesia 6.5, oxide of iron 7.5, oxide of manganese 4.75, and oxide of titanium 0.5. It occurs massive, in angulo-granular concretions, and

in rhomboidal dodecahedrons, whose surfaces have a melted appearance. It is the resinous garnet of Haüy and Jameson. It is found in magnetic ironstone at Arendal in Norway. It occurs also in Piedmont and Ceylon.*

Combination. The intimate union of the particles of different substances by chemical attraction, so as to form a compound possessed of new and peculiar properties. See Attraction, Equivalent, and Gas.

*Combustible. A body which, in its rapid union with others, causes a disengagement of heat and light. To determine this rapidity of combination, or intensity of chemical action, a certain elevation of temperature is necessary, which differs for every different combustible. This difference thrown into a tabular form, would constitute their scale of *accendibility*, or degree of accension.

Stahl adopted, and refined on the vulgar belief of the heat and light coming from the combustible itself; Lavoisier advanced the opposite and more limited doctrine, that the heat and light proceeded from the oxygenous gas, in air and other bodies, which he regarded as the true *pabulum* of fire. Stahl's opinion is perhaps more just than Lavoisier's; for many combustibles burn together, without the presence of oxygen or of any analogous fancied supporters; as chlorine, and the adjuncts to oxygen, have been unphilosophically called. Sulphur, hydrogen, carbon, and azote, are as much entitled to be styled *supporters*, as oxygen and chlorine; for potassium burns vividly in sulphuretted hydrogen, and in prussine, and most of the metals burn with sulphur alone. Heat and light are disengaged, with a change of properties, and reciprocal saturation of the combining bodies. All the combustible gases are certainly capable of affording heat, to the degree of incandescence, as is shown by their mechanical condensation.

Sound logic would justify us in regarding oxygen, chlorine, and iodine, to be in reality combustible bodies; perhaps more so, than those substances vulgarly called combustible. Experiments with the condensing syringe, and the phenomena of the decomposition of *euchlorine*, prove that light as well as heat, may be afforded by oxygen and chlorine. If the body, therefore, which emits, or can emit, light and heat in copious streams, by its action on others, be a combustible, then chlorine and oxygen merit that designation, as much as charcoal and sulphur. Azote is declared by the expounders of the Lavoisierian creed, to be a simple *incombustible*. Yet its mechanical condensation proves that it can afford, from its own resources, an incandescent heat; and with chlorine, iodine, and metallic oxides, all incombustibles on the antiphlogistic notion, it forms compounds possessed of combustible properties, in a pre-eminent and a tremendous degree of concentration. It is melancholy to reflect with what easy credulity, the fictions of the Lavoisierian faith have been received and propagated by chemical compilers, sometimes sufficiently incredulous on subjects of rational belief. *See the next article.*

The electric polarities unquestionably show, what no person can wish to deny, that between oxygen, chlorine, iodine, on one hand, and hydrogen, charcoal, sulphur, phosphorus, and the metals, on the other, there exist striking differences. The former are attracted by the positive pole, the latter by the negative, in voltaic arrangements. But still nothing definitive can be inferred from this fact; because in the actions of what are called combustibles, on each other, without the presence of the other class, we have an exhibition of opposite electrical polarities. Sulphur and metallic plates, by mutual friction or mere contact, produce electrical changes, which apparently prove that sulphur should be ranked along with oxygen, chlorine, and acids, apart from combustibles, whose polarities are negative. Sulphuretted hydrogen in its electrical relations to metals, ranks also with oxygen and acids. How vague and fallacious a rule of classification electrical polarity would afford, may be judged of from the following unquestionable facts; "Among the substances that combine chemically, all those, the electrical energies of which are well known, exhibit opposite states; thus copper and zinc, gold and quicksilver, sulphur and the metals, the acid and alkaline substances, afford opposite instances. In the voltaic combination of diluted nitrous acid, zinc and copper, as is well known, the side of the zinc exposed to the acid is positive. But in combinations of zinc, water, and diluted nitric acid, the surface exposed to the acid is negative; though if the chemical action of the acid on the zinc had been the cause of the effect, it ought to be the same in both cases." *On some chemical agencies of electricity by Sir H. Davy, Phil. Trans.* 1807.

Combustibles have been arranged into simple and compound. The former consist of hydrogen, carbon, boron, sulphur, phosphorus, and nitrogen, besides all the metals. The latter class comprehends the hydrurets, carburets, sulphurets, phosphurets, metallic alloys, and organic products.*

*Combustion. The disengagement of heat and light which accompanies chemical combination. It is frequently made to be synonymous with inflammation, a term which might be restricted, however, to that peculiar species of combustion, in which gaseous matter is burned. Ignition is the incandescence of a body, produced by extrinsic means, without change of its chemical constitution.

Becher and Stahl, feeling daily the necessity of fire to human existence, and astonished with the *metamorphoses* which this power seemed to cause charcoal, sulphur, and metals to undergo, came to regard combustion as the single phenomenon of chemistry. Under this impression Stahl framed his chemical system, the *Theoria Chemiæ Dogmaticæ*, a title characteristic of the dogmatic spirit with which it was inculcated by chemical professors, as the infallible code of their science for almost a century. When the discoveries of Scheele, Cavendish, and Priestley. had fully demonstrated the essential part which air played, in many instances of combustion, the French school made a small modification of the German hypothesis. Instead of supposing, with Stahl, that the heat and light were occasioned by the *emission* of a *common* inflammable principle from the combustible itself, Lavoisier and his associates dexterously availed themselves of Black's hypothesis of latent heat, and maintained, that the heat and light emanated from the oxygenous air, at the moment of its union or fixation with the inflammable basis. How thoroughly the chemical mind has been perverted by these conjectural notions, all our existing systems of chemistry, with *one* exception, abundantly prove.

Dr. Robison, in his preface to Black's lectures, after tracing with perhaps superfluous zeal, the expanded ideas of Lavoisier, to the neglected germs of Hooke and Mayhów, says, "This doctrine concerning combustion, the great, the characteristic phenomenon of chemical nature, has at last received almost universal adoption, though not till after considerable hesitation and opposition; and it has made a complete revolution in chemical science." The French theory of chemistry, as it was called, or hypothesis of combustion, as it should have been named, was for some time classed in certainty with the theory of gravitation.— Alas! it is vanishing with the luminous phantoms of the day, but the sound logic, the pure candour, the numerical precision of inference, which characterize Lavoisier's elements, will cause his name to be held in everlasting admiration.

It was the rival logic of Sir H. Davy, aided by his unrivalled felicity of investigation, which first recalled chemistry from the pleasing labyrinths of fancy, to the more arduous but far more profitable and progressive career of reason. His researches on combustion and flame, already rich in blessings to mankind, would alone place him in the first rank of scientific genius. I shall give a pretty copious account of them, since by some fatality it has happened, that in our best and largest system, where so many pages are devoted to the reveries of ancient chemists, the splendid and useful truths, made known by the great chemist of England, have been totally overlooked.

Whenever the chemical forces, which determine either combination or decomposition, are energetically exercised, the phenomena of combustion, or incandescence with a change of properties, are displayed. The distinction, therefore, between supporters of combustion and combustibles, on which some late systems are arranged, is frivolous and partial. In fact, one substance frequently acts in both capacities, being a supporter *apparently* at one time, and a *combustible* at another. But in both cases the heat and light depend on the same cause, and merely indicate the energy and rapidity with which reciprocal attractions are exerted.

Thus, sulphuretted hydrogen is a combustible with oxygen and chlorine; a supporter with potassium. Sulphur, with chlorine and oxygen, has been called a combustible basis; with metals it acts the part of a supporter; for incandescence and reciprocal saturation result. In like manner, potassium unites so powerfully with arsenic and tellurium as to produce the phenomena of combustion. Nor can we ascribe the phenomena to extrusion of latent heat, in consequence of condensation of volume. The protoxide of chlorine, a body destitute of any combustible constituent, at the instant of decomposition, evolves light and heat with explosive violence; and its volume becomes one-half greater. Chloride and iodide of azote, compounds alike destitute of any inflammable matter, according to the ordinary creed, are resolved into their respective elements with tremendous force of inflammation; and the first expands into more than 600 times its bulk. Now, by the prevailing hypothesis of latent heat, instead of heat and light, a prodigious *cold* ought to accompany such an expansion. The chlorates and nitrates, in like manner, treated with charcoal, sulphur, phosphorus, or metals, deflagrate or detonate, while the volume of the combining substances is greatly enlarged. The same thing may be said of the nitrogurets of gold and silver. In truth, the combustion of gunpowder, a phenomenon too familiar to mankind, should have been a bar to the reception of Lavoisier's hypothesis of combustion. The subterfuges which have been adopted, and admitted, in order to reconcile them, are unworthy to be detailed.

From the preceding facts it is evident 1st, That combustion is not necessarily dependent on the agency of oxygen; 2d, That the evolution of the heat is not to be ascribed simply to a gas parting with its latent store of that ethereal fluid, on its fixation, or combustion; and, 3dly; That "no peculiar substance or form of matter is necessary for producing the effect, but that it is a *general* result of the actions of any substances possessed of strong chemical attractions, or different electrical relations, and that it takes place in all cases in which an intense and violent motion, can be conceived to be communicated to the corpuscles of bodies."

All chemical phenomena indeed may be justly ascribed to motions among the ultimate particles of matter, tending to change the constitution of the mass.

It was fashionable for a while, to attribute the caloric evolved in combustion to a diminished capacity for heat of the resulting substance. Some phenomena, inaccurately observed, gave rise to this generalization. On this subject I shall content myself with stating the conclusions to which MM. Dulong and Petit have come, in consequence of their own recent researches on the laws of heat, and those of Berard and Delaroche. "We may likewise," say these able chemists, "deduce from our researches another very important consequence for the general theory of chemical action, that the quantity of heat developed at the instant of the combination of bodies, has no relation to the capacity of the elements, and that in the greatest number of cases, this loss of heat is not followed by any diminution in the capacity of the compounds formed. Thus, for example, the combination of oxygen and hydrogen, or of sulphur and lead, which produces so great a quantity of heat, occasions no greater alteration in the capacity of water, or of sulphuret of lead, than the combination of oxygen with copper, lead, silver, or of sulphur with carbon, produces in the capacities of the oxides of these metals, or of carburet of sulphur."—"We conceive that the relations which we have pointed out between the specific heats of simple bodies, and of those of their compounds, prevent the possibility of supposing, that the heat developed in chemical actions, owes its origin merely to the heat produced by change of state, or to that supposed to be combined with the material molecules;" *Annales de Chimie et Physique*, x.

Mr. Dalton, in treating of the constitution of elastic fluids, lays it down as an axiom, that diminution of volume is the criterion of chemical affinity being exercised; and hence maintains, that the atmospheric air is a mere mixture. Thus, also, the extrication of heat from chemical union, has been usually referred to the condensation of volume. The following examples will show the fallacy of such crude hypotheses. 1. Chlorine and hydrogen mixed, explode by the sunbeam, electric spark, or inflamed taper with the disengagement of much heat and light; and the volume of the mixture, which is greatly *enlarged* at the instant of combination, suffers no condensation afterwards. Muriatic acid gas, having the mean density of its components, is produced. 2. When one volume of olefiant gas and one of oxygen are detonated together, three and a half gaseous volumes result, the greater part of the hydrogen remains untouched, and a volume and a half of carbonic oxide is formed, with about 1-10th of carbonic acid. 3. The following experiments of M. Gay-Lussac on liquid combinations are to the same purpose. 1. A saturated solution of nitrate of ammonia, at the temperature of 61°, and of the density 1.302, was mixed with water in the proportion of 44.05. to 33.76. The temperature of the mixture sank 8.9°; but the density at 61° was 1.159, while the mean density was only 1.151. 2. On adding water to the preceding mixture, in the proportion of 33.64 to 39.28, the temperature sank 3.4°, while the density continued 0.003 above the mean. Other saline solutions presented the same result, though none to so great a degree.

That the internal motions which accompany the change in the *mode* of combination, independent of change of *form*, occasion the evolution of heat and light, is evident from the following observations of Berzelius:—In the year 1811, when he was occupied with examining the combinations of antimony, he discovered, accidentally, that several metalline antimoniates, when they begin to grow red-hot, exhibit a sudden appearance of fire, and then the temperature again sinks to that of the surrounding combustibles. He made numerous experiments to elucidate the nature of this appearance, and ascertained that the weight of the salt was not altered, and that the appearance took place without the presence of oxygen. Before the appearance of fire, these salts are very easily decomposed, but afterwards they are attacked neither by acids nor alkaline leys—a proof that their constituents are now held together by a stronger affinity, or that they are more intimately combined. Since that time he has observed these appearances in many other bodies, as, for example, in green oxide of chromium, the oxides of tantalum and rhodium. (See Chromium.)

Mr. Edmund Davy found, that when a neutral solution of platinum was precipitated by hydro-sulphuret of potash, and the precipitate dried in air deprived of oxygen, a black compound was obtained, which when heated out of the contact of air, gave out sulphur, and some sulphuretted hydrogen gas, while a combustion similar to that in the formation of the metallic sulphurets appeared, and common sulphuret of platinum remained behind. When we heat the oxide of rhodium, obtained from the soda-muriate, water first comes over; and on increasing the temperature, combustion takes place, oxygen gas is suddenly disengaged, and a suboxide of rhodium remains behind The two last cases are analogous to that of the protoxide of chlorine, the *euchlorine* of Sir H. Davy. Gadolinite, the siliciate of yttria, was first observed by Dr. Wollaston to display a similar lively incandescence.—The variety of this mineral with a glassy fracture, answers better than the splintery variety. It is to be heated before the blowpipe, so that the whole piece becomes equally hot. At a red-heat it catches fire. The colour becomes greenish-gray, and the solubility in acids is destroyed. Two small pieces of gadolinite, one of which had been heated to redness, were put in aqua regia; the first was dissolved in a few hours; the second was not attacked in two months. Finally, Sir H. Davy observed a similar phenomenon on heating hydrate of zirconia.

The *verbal* hypothesis of thermoxygen by Brugnatelli, with Dr. Thomson's supporters, partial supporters, and semicombustion, need not detain us a moment from the substantial facts, the noble truths, first revealed by Sir H Davy, concerning the mysterious process of combustion. Of the researches which brought them to light, it has been said, without any hyperbole, that "if Bacon were to revisit the earth, this is exactly such a case as we should chuse to place before him, in order to give him, in a small compass, an idea of the advancement which philosophy has made since the time, when he had pointed out to her the route which she ought to pursue."

The coal mines of England, alike essential to the comfort of her population and her financial resources, had become infested with fire-damp, or inflammable air, to such a degree as to render the mutilation and destruction of the miners, by frequent and tremendous explosions, subjects of sympathy and dismay to the whole nation. By a late explosion in one of the Newcastle collieries, no less than one hundred and one persons perished in an instant; and the misery heaped on their forlorn families, consisting of more than three hundred persons, is inconceivable. To subdue this gigantic power was the task which Sir H. Davy assigned to himself; and which, had his genius been baffled, the kingdom could scarcely hope to see achieved by another. But the stubborn forces of nature can only be conquered, as Lord Bacon justly pointed out, by examining them in the nascent state, and subjecting them to experimental interrogation, under every diversity of circumstance and form. It was this investigation, which first laid open the hitherto unseen and inaccessible sanctuary of *Fire.*

As some invidious attempts, however, have been made, to insinuate that Sir H. Davy stole the germ of his discoveries from the late Mr. Tennant, it may be proper to preface the account of them by the following extract from "Resolutions of a Meeting held for considering the facts relating to the Discovery of the Lamp of Safety."

"*Soho Square, Nov.* 20, 1817.

"3d—That Sir H. Davy not only discovered, independently of all others, and without any knowledge of the unpublished experiments of the late Mr. Tennant on Flame, the principle of the non-communication of explosions through small apertures, but that he has also the sole merit of having first applied it to the very important purpose of a safety-lamp, which has evidently been imitated in the latest lamps of Mr. George Stephenson.

(Signed) Joseph Banks, P. R. S.
William J. Brande,
Charles Hatchett,
William Hyde Wollaston,
Thomas Young."

See the whole document in Tilloch's Magazine, vol. 50. p. 387.

The phenomena of combustion may be conveniently considered under six heads; 1*st*. The temperature necessary to inflame different bodies. 2*d*, The nature of flame, and the relation between the light and heat which compose it. 3*d*. The heat disengaged by different combustibles in burning. 4*th*, The causes which modify and extinguish combustion, and of the safe-lamp. 5*th*, Invisible combustion 6*th*, Practical Inferences.

1*st*. *Of the temperature necessary to inflame different bodies.* 1*st*. A simple experiment shows the successive combustibilities of different bodies. Into a long bottle with a narrow neck, introduce a lighted taper, and let it burn till it is extinguished. Carefully stop the bottle and introduce another lighted taper. It will be extinguished, before it reaches the bottom of the neck. Then introduce a small tube, containing zinc and dilute sulphuric acid, at the aperture of which the hydrogen is inflamed. The hydrogen will be found to burn in whatever part of the bottle the tube is placed. After the hydrogen is extinguished, introduce lighted sulphur. This will burn for some time; and after its extinction phosphorus will be as luminous as in the air, and, if heated in the bottle, will produce a pale yellow flame of considerable density.

Phosphorus is said to take fire when heated to 150° and sulphur to 550°. Hydrogen inflames with chlorine at a lower temperature than with oxygen. By exposing oxygen and hydrogen, confined in glass tubes, to a very dull red (about 800 F.) they explode. When the heat was about 700 F. they combine rapidly with a species of silent combustion. A mixture of common air and hydrogen was introduced into a small copper tube, having a stopper not quite tight; the copper tube was placed in a charcoal fire; before it became visibly red-hot an explosion took place, and the stopper was driven out. We see, therefore, that the inflaming temperature is independent of compression or rarefaction.

The ratio of the combustibility of the different gaseous matters, is likewise to a certain extent, as the masses of heated matters required to inflame them. Thus, an iron wire 1-40th of an inch, heated cherry-red, will not inflame olefiant gas, but it will inflame hydrogen gas. A wire of 1-8th, heated to the same degree, will inflame olefiant gas. But a wire $\frac{1}{500}$ of an inch, must be heated to whiteness to inflame hydrogen, though at a low red-heat it will inflame bi-phosphuretted gas. Yet wire of 1-40th, heated even to whiteness, will not inflame mixtures of fire-damp. Carbonic oxide inflames in the atmosphere when brought into contact with an iron wire heated to dull redness; whereas carburetted hydrogen is not inflammable, unless the iron is heated to whiteness, so as to burn with sparks.

These circumstances will explain, why a mesh of wire, so much finer or smaller, is required to prevent the explosion from hydrogen and oxygen, from passing; and why so course a texture and wire are sufficient to prevent the explosion of the fire-damp, fortunately the least combustible of all the inflammable gases known. The flame of sulphur, which kindles at so low a temperature, will exist under refrigerating processes, which extinguish the flame of hydrogen and all carburetted gases.

Let the smallest possible flame be made by a single thread of cotton immersed in oil, and burning immediately upon the surface of the oil. it will be found to yield a flame about 1-30th of an inch in diameter. Let a fine iron wire of $\frac{1}{180}$ of an inch, made into a ring of 1-10th of an inch diameter, be brought over the flame. Though at such a distance, it will instantly extinguish the flame, if it be *cold;* but if it be held above the flame, so as to be slightly heated, the flame may be passed through it without being extinguished. That the effect depends entirely on the power of the metal to abstract the heat of flame, is shown by bringing a glass capillary ring of *the same* diameter and size over the flame. This being a much worse conductor of heat, will not, even when cold, extinguish it. If its size, however, be made greater, and its circumference smaller, it will act like the metallic wire, and require to be heated to prevent it from extinguishing the flame. Now, a flame of sulphur may be made much smaller than that of hydrogen; one of hydrogen may be made much smaller than that of a wick fed with oil; and that of a wick fed with oil smaller than that of carburetted hydrogen. A ring of cool wire, which instantly extinguishes the flame of carburetted hydrogen, diminishes but slightly the size of a flame of sulphur, of the same dimensions.

By the following simple contrivance, we may determine the relative facility of burning, among different combustibles. Prepare a series of metallic globules of different sizes, by fusion at the end of iron wires, and light a series of very minute flames of different bodies all of one size. If a globule -20th of an inch diameter be brought near an oil flame of 1-30th in diameter, it will extinguish it, when cold, at the distance of a diameter. The size of the spherule, adequate to the extinction of the particular flame, will be a measure of its combustibility. If the globule be heated, however, the distance will diminish at which it produces extinction. At a white heat, the globule, in the above instance, does not extinguish it by actual contact, though at a dull red-heat it immediately produces the effect.

2d. *Of the nature of flame, and of the relation between the light and the heat which compose it.* The flame of combustible bodies may in all cases be considered, as the combustion of an *explosive mixture* of inflammable gas, or vapour, with air. It cannot be regarded as a mere combustion, at the surface of contact, of the inflammable matter. This fact is proved by holding a taper, or a piece of burning phosphorus, within a large flame made by the combustion of alcohol. The flame of the taper, or of the phosphorus, will appear in the centre of the other flame, proving that there is oxygen even in its interior part. When a wire-gauze safe-lamp is made to burn in a very explosive mixture of coal-gas and air, the light is feeble and of a pale colour. Whereas the flame of a current of coal gas burnt in the atmosphere, as is well known by the phenomena of the gas lights, is extremely brilliant. It becomes, therefore, a problem of some interest, "Why the combustion of explosive mixtures, under different circumstances, should produce such different appearances?" In reflecting on the circumstances of these two species of combustion, Sir H. Davy was led to imagine that the cause of the superiority of the light of the *stream* of coal gas, might be owing to the *decomposition* of a part of the gas, towards the interior of the flame, where the air was in the smallest quantity, and the deposition of solid charcoal, which first by its *ignition*, and afterwards by its *combustion*, increased, in a high degree, the intensity of the light. The following experiments show, that this is the true solution of the problem.

If we hold a piece of wire-gauze, of about 900 apertures to the square inch, over a stream of coal gas issuing from a small pipe, and if we inflame the gas above the wire-gauze, left almost in contact with the orifice of the pipe, it burns with its usual bright light. On raising the wire-gauze so as to cause the gas to be mixed with more air before it inflames, the light becomes feebler, and at a certain distance the flame assumes the precise character of that of an explosive mixture burning within the lamp. But though the light is so feeble in this case, the heat is greater than when the light is much more vivid. A piece of wire of platina, held in this feeble blue flame, becomes instantly white-hot.

On reversing the experiment by inflaming a stream of coal-gas, and passing a piece of wire gauze gradually from the summit of the flame to the orifice of the pipe, the result is still more instructive. It is found that the apex of the flame, intercepted by the wire-gauze, affords no solid charcoal; but in passing it downwards, solid charcoal is given off in considerable quantities, and prevented from burning by the cooling agency of the wire-gauze. At the bottom of the flame, where the gas burned blue, in its immediate contact with the atmosphere, charcoal ceased to be deposited in visible quantities.

The principle of the increase of the brilliancy and density of flame, by the production and ignition of solid matter, appears to admit of many applications. Thus, olefiant gas gives the most brilliant white light of all combustible gases, because, as we learn from Berthollet's experiments, related under carburetted hydrogen, at a very high temperature, it deposites a very large quantity of solid carbon. Phosphorus, which rises in vapour at common temperatures, and the vapour of which combines with oxygen at those temperatures, is always luminous; for each particle of acid formed, must, there is every reason to believe, be white-hot. So few of these particles, however, exist in a given space, that they scarcely raise the temperature of a solid body exposed to them, though, as in the rapid combustion of phosphorus, where immense numbers are existing in a small space, they produce a most intense heat.

The above principle readily explains the appearances of the different parts of the flames of burning bodies, and of flame urged by the blow-pipe. The point of the inner blue flame, where the heat is greatest, is the point where the whole of the charcoal is burned in its gaseous combinations, without previous deposition.

It explains also the intensity of the light of those *flames* in which *fixed* solid matter is produced in combustion, such as the flame of phosphorus and of zinc in oxygen, &c. and of potassium in chlorine, and the feebleness of the light of those flames in which gaseous and volatile matter alone is produced, such as those of hydrogen and of sulphur in oxygen, phosphorus in chlorine, &c.

It offers means of increasing the light of certain burning substances, by placing in their flames even incombustible substances. Thus the intensity of the light of burning sulphur, hydrogen, carbonic oxide, &c. is wonderfully increased by throwing into them oxide of zinc, or by placing in them very fine amianthus or metallic gauze.

It leads to deductions concerning the chemical nature of bodies, and various phenomena of their decomposition. Thus ether burns with a flame, which seems to indicate the presence of olefiant gas in that substance. Alcohol burns with a flame similar to that of a mixture of carbonic oxide and hydrogen. Hence the first is probably a binary compound of olefiant gas and water, and the second of carbonic oxide and hydrogen. When protochloride of copper is introduced into the flame of a candle or lamp, it affords a peculiar dense and brilliant red light, tinged with green and blue towards the edges, which seems to depend upon the chlorine being separated from the copper by the hydrogen, and the ignition and combustion of the solid copper and charcoal.

Similar explanations may be given of the phenomena presented by the action of other combinations of chlorine on flame; and it is probable, in many of those cases, when the colour of flame is changed by the introduction of incombustible compounds, that the effect depends on the production, and subsequent ignition or combustion of inflammable matter from them. Thus the rose-coloured light given to flame by the compounds of strontium and calcium, and the yellow colour given by those of barium, and the green by those of boron, may depend upon a temporary production of these bases, by the inflammable matter of the flame. Dr. Clarke's experiments on the reduction of barytes, by the hydroxygen lamp, is favourable to this idea. Nor should any supposed inadequacy of heat in ordinary flame, prevent us from adopting this conclusion. Flame, or gaseous matter heated so highly as to be luminous, possesses a temperature beyond the white heat of solid bodies, as is shown by the circumstance, that air not luminous will communicate this degree of heat. This is proved by a simple experiment. Hold a fine wire of plantinum about 1-20th of an inch from the exterior of the middle of the flame of a spirit-lamp, and conceal the flame by an opaque body. The wire will become white-hot in a space, where there is no visible light. The real temperature of visible flame is perhaps as high as any we are acquainted with. Mr. Tennant used to illustrate this position, by fusing a small filament of platinum, in the flame of a common candle.

These views will probably offer illustrations of electrical light. The voltaic arc of flame from the great battery, differs in colour and intensity, according to the substances employed in the circuit, and is infinitely more brilliant and dense with charcoal than with any other substance. May not this depend, says Sir H. Davy, upon particles of the substances separated by the electrical attractions? And the particles of charcoal, being the lightest among solid bodies (as their prime equivalent shows), and the least coherent, would be separated in the largest quantities.

The heat of flames may be actually diminished by increasing their light (at least the heat communicable to other matter) and *vice versa*. The flame from combustion, which produces the most intense heat amongst those which have been examined, is that of a mixture of oxygen and hydrogen compressed in Newman's blow-pipe apparatus. (See Blow-Pipe). This flame is hardly visible in bright day-light, yet it instantly fuses the most refractory bodies; and the light from solid bodies ignited in it, is so vivid as to be painful to the eye. This application certainly originated from Sir H. Davy's discovery, that the explosion from oxygen and hydrogen would not communicate through very small apertures, and he himself first tried the experiment with a fine glass capillary tube. The flame was not *visible* at the end of this tube, being overpowered by the brilliant star of the glass, ignited at the aperture.

3. *Of the heat disengaged by different combustibles in the act of burning.*

Lavoisier, Crawford, Dalton, and Rumford, in succession, made experiments to determine the quantity of heat evolved in the combustion of various bodies. The apparatus used by the last was perfectly simple, and perhaps the most precise of the whole. The heat was conducted by flattened pipes of metal, into the heart of a body of water, and was measured by the temperature imparted. The following is a general table of results:—

Substances burned, 1 lb.	Oxygen consumed in lbs.	Ice melted in lbs.			
		Lavoisier.	Crawford.	Dalton.	Rumford.
Hydrogen, - -	7.5	295.6	480	320	
Carburetted hydrogen,	4			85	
Olefiant gas, - -	3.50			88	
Carbonic oxide, -	0.58			25	
Olive oil, - -	3.00	149	89	104	94.07
Rape oil, - -	3.0				124.10
Wax, - - -	3.0	133	97	104	126.24
Tallow, - -	3.0	96		104	111.58
Oil of turpentine, -				60	
Alcohol, - - -	2.07			58	67.47
Ether sulphuric, -	3			62	107.03
Naphtha, - - -					97.83
Phosphorus, - -	1.33	100		60	
Charcoal, - -	2.66	96.5	69	40	
Sulphur, - -	1.00			20	
Camphor, - -				70	
Caoutchouc, - -				42	

The discrepancies in the preceding table, are sufficient to show the necessity of new experiments on the subject. Count Rumford made a series of experiments on the heat given out during the combustion of different woods. He found that one pound of wood by burning, produced as much heat as would have melted from about 34 to 54 pounds of ice. The average quantity is about 40. MM. Clement and Desormes find that woods give out heat in the ratio of their respective quantities of carbon; which they state to be equal to one half of their total weight. Hence they assign 48 pounds as the quantity of ice melted, in burning one of wood. In treating of acetic acid and carbon, I have already taken occasion to state, that they appear greatly to overrate the proportion of carbon in woods.

The preceding table is incorrectly given in several respects by our systematic writers; Dr. Thomson, for example, states, that 1 pound of hydrogen consumes only 6 pounds of oxygen, though the saturating proportion assigned by him is 8 pounds. The proportions of oxygen consumed by olive oil, phosphorus, charcoal, and sulphur, are all in like manner erroneous.

In vol. i. p. 184. of Dr. Black's lectures, we have the following notes. "100 pounds weight of the best Newcastle coal, when applied by the most judiciously constructed furnace, will convert about 1½ wine hogsheads of water, into steam that supports the pressure of the atmosphere." 1½ hogsheads of water, weigh about 790 pounds. Hence 1 part of coal will convert nearly 8 parts of water into steam. Count Rumford says, that the heat generated in the combustion of 1 pound of pit coal, would make $36\frac{3}{10}$ pounds of ice-cold water boil. But we know that it requires fully 5½ times as much heat to convert the boiling water into steam. Therefore, $\frac{36.3}{5.5} = 6\frac{2}{3}$, is the weight of water that would be converted into steam by one pound of coal.

Mr. Watt found, that it requires 8 feet surface of boiler to be exposed to fire to boil off one cubic foot of water per hour, and that a bushel, or 84 pounds of Newcastle coal so applied, will boil off from 8 to 12 cubic feet. He rated the heat expended in boiling off a cubic foot of water, to be about six times as much as would bring it to a boiling heat from the medium temperature (55°), in this climate. The mean quantity is 10 cubic feet, which weigh 625 pounds. Hence 1 pound of coal burnt, is equivalent to boil off in steam, nearly $7\frac{1}{2}$ lbs. of water, at the temperature of 55°.

In situations where wood was employed for fuel to Mr. Watt's engines, he allowed three times the weight of it, that he did of Newcastle coal. The cubical coal of the Glasgow coal district, is reckoned to have only $\frac{3}{4}$ the calorific power of the Newcastle coal; and the small coal or culm, requires to be used in double weight, to produce an equal heat with the larger pieces. A bushel of Newcastle coal is equivalent to a hundred weight of the Glasgow.

I shall now describe the experiments recently made on this subject by Sir H. Davy, subservient to his researches on the nature of flame. A mercurial gas-holder, furnished with a system of stop-cocks, terminated in a strong tube of platinum, having a minute aperture. Above this, was fixed a copper cup filled with olive oil, in which a thermometer was placed. The oil was heated to 212°, to prevent any difference in the communication of heat, by the condensation of aqueous vapour; the pressure was the same for the different gases, and they were consumed as nearly as possible in the same time, and the flame applied to the same point of the copper cup, the bottom of which was wiped after each experiment. The results were as follows:—

Substances.	Rise of therm. from 212° to	Oxygen consumed.	Ratios of heat.
Olefiant gas,	270°	6.0	9.66
Hydrogen,	238	1.0	26.0
Sulph. hydrogen,	232	3.0	6.66
Coal gas,	236	4.0	6.00
Carbonic oxide,	218	1.0	6.00

The *data* on which Sir H. calculates the ratios of heat, are the elevations of temperature, and the quantities of oxygen consumed conjointly. We see that hydrogen produces more heat in combustion than any of its compounds, a fact accordant with Mr. Dalton's results in the former table; only Sir H. Davy's ratio is more than double that of Mr. Dalton's, as to hydrogen, and carburetted hydrogen. On this point, however, Sir H. with his usual sagacity remarks, that it will be useless to reason upon the ratios as exact, for charcoal was deposited from both the olefiant gas and coal gas during the experiment, and much sulphur was deposited from the sulphuretted hydrogen. It confirms, however, the general conclusions, and proves that hydrogen stands at the head of the scale, and carbonic oxide at the bottom. It might at first view be imagined, that, according to this scale, the flame of carbonic oxide ought to be extinguished by rarefaction at the same degree as that of carburetted hydrogen; but it must be remembered, as has been already shown, that carbonic oxide is a much more easily kindled, a more accendible gas.

4. *Of the causes which modify or extinguish combustion or flame.*

The earlier experimenters upon the Boylean vacuum observed, that flame ceased in highly rarefied air; but the degree of rarefaction necessary for this effect has been differently stated. On this point, Sir H. Davy's investigations are peculiarly beautiful and instructive. When hydrogen gas, slowly produced from a proper mixture, was inflamed at a fine orifice of a glass tube, as in Priestley's philosophical candle, so as to make a jet of flame of about 1-6th of an inch in height, and introduced under the receiver of an air-pump, containing from 200 to 300 cubical inches of air, the flame enlarged as the receiver became exhausted; and when the gauge indicated a pressure, between 4 and 5 times less than that of the atmosphere, was at its maximum of size; it then gradually diminished below, but burned above, till its pressure was between 7 and 8 times less: when it became extinguished

To ascertain whether the effect depended upon the deficiency of oxygen, he used a larger jet with the same apparatus, when the flame to his surprise, burned longer; even when the atmosphere was rarefied 10 times; and this in repeated trials. When the larger jet came white-hot, and continued red-hot till the flame was extinguished. It immediately occurred to him, that the heat communicated to the gas by this tube, was the cause that the combustion continued longer in the last trials when the larger flame was used; and the following experiments confirmed the conclusion. A piece of wire of platinum was coiled round the top of the tube, so as to reach into and above the flame.—The jet of gas of 1-6th of an inch in height was lighted, and the exhaustion made.—The wire of platinum soon became white-hot in the centre of the flame, and a small point of wire near the top fused. It continued white-hot, till the pressure was 6 times less. When it was 10 times, it continued red-hot at the upper part, and as long as it was dull red, the gas, though certainly ex-

and this isin repeated trials. When the larger

tinguished below, continued to burn in contact with the hot wire, and the combustion did not cease, until the pressure was reduced 13 times.

It appears from this result, that the flame of hydrogen is extinguished in rarefied atmospheres, only when the heat it produces is insufficient to keep up the combustion: which appears to be when it is incapable of communicating visible ignition to metal; and as this is the temperature required for the inflammation of hydrogen, (see section 1st,) at common pressure, it appears that its *combustibility* is neither diminished nor increased by rarefaction from the removal of pressure.

According to this view, with respect to hydrogen, it should follow, that those amongst other combustible bodies, which require less heat for their accension, ought to burn in more rarefied air than those that require more heat; and those which *produce* much heat in their combustion ought to burn, other circumstances being the same, in more rarefied air, than those that produce little heat. Every experiment since made, confirms these conclusions. Thus olefiant gas, which approaches nearly to hydrogen, in the temperature produced by its combustion, and which does not require a much higher temperature for its accension, when its flame was made by a jet of gas from a bladder connected with a small tube, furnished with a wire of plantinum, under the same circumstances as hydrogen, ceased to burn when the pressure was diminished between 10 and 11 times. And the flames of alcohol and of the wax taper, which require a greater consumption of caloric for the volatilization and decomposition of their combustible matter, were extinguished when the pressure was 5 or 6 times less without the wire of platinum, and 7 or 8 times less when the wire was kept in the flame. Light carburetted hydrogen, which produces, as we have seen, less heat in combustion than any of the common combustible gases, except carbonic oxide, and which requires a higher temperature for its accension than any other, has its flame extinguished, even though the tube was furnished with the wire when the pressure was below 1-4th.

The flame of carbonic oxide, which though it produces little heat in combustion, is as accendible as hydrogen, burned when the wire was used, the pressure being 1-6th.

The flame of sulphuretted hydrogen, the heat of which is in some measure carried off by the sulphur, produced by its decomposition during its combustion in rare air, when burned in the same apparatus as the olefiant and other gases, was extinguished when the pressure was 1-7th.

Sulphur, which requires a lower temperature for its accension, than any common inflammable substance, except phosphorus, burned with a very feeble blue flame in air rarefied 15 times; and at this pressure the flame heated a wire of plantinum to dull redness; nor was it extinguished till the pressure was reduced to 1-20th. From the preceding experimental facts we may infer, that the taper would be extinguished at a height of between 9 and 10 miles, hydrogen between 12 and 13; and sulphur between 15 and 16.

Phosphorus, as has been shown by M. Van Marum, burns in an atmosphere rarefied 60 times. Sir H. Davy found, that phosphuretted hydrogen produced a flash of light when admitted into the best vacuum that could be made, by an excellent pump of Nairn's construction.

Chlorine and hydrogen inflame at a much lower temperature, than oxygen and hydrogen. Hence the former mixture explodes when rarefied 24 times; the latter ceases to explode when rarefied 18 times. Heat extrinsically applied, carries on combustion, when it would otherwise be extinguished. Camphor in a thick metallic tube, which disperses the heat, ceases to burn in air rarefied 6 times; in a glass tube which becomes ignited, the flame of camphor exists under a ninefold rarefaction. Contact with a red-hot iron, makes naphtha glow with a lambent flame at a rarefaction of 30 times; though without foreign heat, its flame dies at an atmospheric rarefaction of 6. If the mixture of oxygen and hydrogen expanded to its non-explosive tenuity; be exposed to the ignition of a glass tube, the electric spark will then cause an explosion, at least in the heated portion of the gases.

We shall now detail briefly the effects of rarefaction by *heat* on combustion and explosion. Under CALORIC we have shown, that air by being heated from 32° to 212° expands $\frac{3}{8}$, or 8 parts become 11; hence the expansion of one volume of air at 212° into 2½, or the augmentation of 1.5 = $\frac{12}{8}$ which Sir H. Davy found to take place when the enclosing glass tube began to soften with ignition, will indicate 932°. For $\frac{3}{8}$: 180° : : $\frac{12}{8}$: 720°, to which if we add 212°, the sum is 932°. One of air at 212 becoming 2¼, as took place in the other experiment of Sir H. Davy, will give us $(180° \times \frac{10}{3}) + 212° = 812°$, for the heat of fusible metal luminous in the shade. I believe these experiments to be much more accurate than any hitherto given, relative to the temperature of incandescence. This philosopher, whose ingenuity of research is usually guided by the most rigorous arithmetic, estimates the first temperature from the above data of Gay-Lussac, at 1035° Farenheit. I therefore hesitate to offer a discordant computation. One volume of air at 212°, should become at a temperature of 1035°, according to the rule I use, 2.715 parts, instead of 2.5.

Sir H. introduced into a small glass tube over well boiled mercury, a mixture of two parts of hydrogen and one of oxygen, and heated the tube by a spirit lamp, till the volume of the gas was increased from 1 to 2.5. By means of a blow-pipe and another lamp, he made the upper part of the tube red-hot, when an explosion instantly took place. This experiment refutes the notions of M. de Grotthus, on the non-explosiveness of that mixture, when expanded by heat.—He introduced into a bladder a mixture of oxygen and hydrogen, and connected this bladder with a thick glass tube of about one-sixth of an inch in diameter, and three feet long, curved so that it could be gradually heated in a charcoal furnace; two spirit-lamps were placed under the tube, where it entered the charcoal fire, and the mixture was very slowly passed through. An explosion took place, before the tube was red-hot. This fine experiment shows, that expansion by heat, instead of diminishing the accendibility of gases, enables them, on the contrary, to explode apparently at a lower temperature; which seems perfectly reasonable, as a part of the heat communicated by any ignited body, must be lost in gradually raising the temperature.

M. de Grotthus has stated, that if a glowing coal be brought into contact with a mixture of oxygen and hydrogen, it only rarefies them, but does not explode them. This depends on the degree of heat communicated by the coal. If it is red in day-light, and free from ashes, it uniformly explodes the mixture. If its redness be barely visible in the shade, it will not explode them, but cause their slow combination. The general phenomenon is wholly unconnected with rarefaction; as is shown by the following circumstance: When the heat is greatest, and before the invisible combination is completed, if an iron wire, heated to whiteness, be placed upon the coal within the vessel, the mixture instantly explodes.

Subcarburetted hydrogen, or fire-damp, as has been shown, requires a very strong heat for its inflammation. It therefore offered a good substance for an experiment, on the effect of high degrees of rarefaction, by heat on combustion. One part of this gas, and eight of air, were mixed together, and introduced into a bladder furnished with a capillary tube. This tube was heated till it began to melt. The mixture was then passed through it, into the flame of a spirit-lamp, when it took fire, and burned with its own peculiar explosive light, beyond the flame of the lamp; and when withdrawn, though the aperture was quite white-hot, it continued to burn vividly.

That the compression in one part of an explosive mixture, produced by the sudden expansion of another part by heat, or the electric spark, is not the cause of combustion, as has been supposed by Mr. Higgins, M. Berthollet, and others, appears to be evident from what has been stated, and is rendered still more so by the following facts: A mixture of bi-phosphuretted hydrogen gas and oxygen, which explode at a heat a little above that of boiling water, was confined by mercury, and very gradually heated on a sand bath. When the temperature of the mercury was 242°, the mixture exploded. A similar mixture was placed in a receiver communicating with a condensing syringe, and condensed over mercury till it occupied only one-fifth of its original volume. No explosion took place, and no chemical change had occurred; for when its volume was restored it was instantly exploded by the spirit-lamp.

It would appear then that *the heat* given out by the compression of gases, is the real cause of the combustion which it produces; and that at certain elevations of temperature, whether in rarefied or compressed atmospheres, explosion or combustion occurs; that is, bodies combine with the production of heat and light.

Since it appears that gaseous matter acquires a double, triple, quadruple, &c. bulk, by the successive increments of 480° F. 2 × 480°, 3 × 480°, &c. we may gain approximations to the temperature of flame, by measuring the expansion of a gaseous mixture at the instant of explosion, provided the resulting compound gas occupy, after cooling, the same bulk as the sum of its constituents. Now this is the case with chlorine and hydrogen, and with prussine and oxygen. The latter detonated in the proportion of one to two, in a tube of about two-fifths of an inch diameter, displaced a quantity of water, which demonstrated an expansion of 15 times their original bulk. Hence 15 × 480° = 7200° of Fahr. and the real temperature is probably much higher; for heat must be lost by communication to the tube and the water. The heat of the gaseous carbon in combustion in this gas, appears more intense than that of hydrogen; for it was found that a filament of platinum was fused by a flame of prussine (cyanogen) in the air, which was not fused by a similar flame of hydrogen.

We have thus detailed the modifications produced in combustion by rarefaction, mechanical and calorific. It remains on this head to state the effects of the mixture of different gases, and those of different cooling orifices, on flame.

In Sir H. Davy's first paper on the fire-damp of coal mines, he mentioned that carbonic acid had a greater influence in destroying the explosive power of mixtures of fire-damp and air, than azote; and he suppose ctn scause to be its greater density and capacity for heat, in consequence of which it might exert a greater cooling agency, and thus prevent the temperature of the mixture from being raised to that degree necessary for combustion. He subsequently made a series of experiments with the view of determining how far this idea is correct, and for the purpose of ascertaining the general phenomena, of the effects of the mixture of gaseous substances upon explosion and combustion.

He took given volumes, of a mixture of two parts of hydrogen and one part of oxygen by measure, and diluting them with various quantities of different elastic fluids, he ascertained at what degree of dilution, the power of inflammation by a strong spark from a Leyden phial was destroyed. He found that for one of the mixture, inflammation was

	Prevented by	*Permitted with.*	*Cooling power, air = 1.*
Of hydrogen,	8	6	2.66
Oxygen,	9	7	1.12
Nitrous oxide,	11	10	0.75 (the mean)
Subcarburetted hydrogen,	1	$\frac{3}{4}$	2.18 (coal gas)
Sulphuretted hydrogen,	2	$1\frac{1}{2}$	
Olefiant gas,	$\frac{1}{2}$	$\frac{1}{3}$	1.6
Muriatic acid gas,	2	$1\frac{1}{2}$	
Chlorine,			0.66
Silicated fluoric gas,	$\frac{10}{12}$	$\frac{9}{12}$	
Azote,			1.33
Carbonic acid,			0.727

The first column of the preceding table shows, that other causes, besides density and capacity for heat, interfere with the phenomena. Thus nitrous oxide, which is nearly one-third denser than oxygen, and which, according to Delaroche and Berard, has a greater capacity for heat, in the ratio of 1.3503 to 0.9765 by volume, has lower powers of preventing explosion. Hydrogen also, which is fifteen times lighter than oxygen, and which in equal volumes has a smaller capacity for heat, certainly has a higher power of preventing explosion; and olefiant gas exceeds all other gaseous substances, in a much higher ratio than could have been expected, from its density and capacity.

I have deduced the third column, from Sir H. Davy's experiments on the relative times in which a thermometer, heated to 160°, when plunged into a volume of 21 cubic inches of the respective gases at 52°, took to cool down to 106°. Where an elastic fluid exerts a cooling influence on a solid surface, the effect must depend principally upon the rapidity with which its particles change their places; but where the cooling particles are mixed throughout a mass with other gaseous particles, their effect must depend principally upon the power they possess of rapidly abstracting heat from the contiguous particles; and this will depend probably upon two causes, the simple abstracting power by which they become quickly heated, and their capacity for heat, which is great in proportion as their temperatures are less raised by this abstraction.—The power of elastic fluids to abstract heat from solids, appears from the above experiments to be in some inverse ratio to their density; and there seems to be something in the constitution of the light gases, which enables them to carry off heat from solid surfaces in a different manner from that in which they would abstract it in gaseous mixtures, depending probably on the mobility of their parts. Those particles which are lightest must be conceived most capable of changing place, and would therefore cool solid surfaces most rapidly; in the cooling of gaseous mixtures, the mobility of the particles can be of little consequence.

Whatever be the cause of the different cooling powers of the different elastic fluids in preventing inflammation, very simple experiments show that they operate uniformly with respect to the different species of combustion; and that those explosive mixtures, or inflammable bodies, which require least heat for their combustion, require larger quantities of the different gases to prevent the effect, and *vice versa*. Thus one of chlorine and one of hydrogen still inflame when mixed with eighteen times their bulk of oxygen; whereas a mixture of carburetted hydrogen and oxygen, in the proper proportions (one and two) for combination, have their inflammation prevented by less than three times their volume of oxygen. A wax taper was instantly extinguished in air mixed with one-tenth of silicated fluoric acid, and in air mixed with one-sixth of muriatic acid gas; but the flame of hydrogen burned readily in those mixtures; and in mixtures which extinguished the flame of hydrogen, the flame of sulphur burned. (*See the beginning of section 1st.*)

In cases, however, in which the heat required for chemical union is very small, as in the instance of hydrogen and chlorine, a mixture which prevents inflammation will not prevent combination, that is, the gases will combine without any flash. If two volumes of carburetted hydrogen be added to a mixture of one of chlorine with one of hydrogen, muriatic acid is formed throughout the mixture and heat produced, as was evident from the expansion when the spark passed, and the rapid contraction afterwards, but the heat was so rapidly carried off by the quantity of carburetted hydrogen, that no flash was visible.

Experiments on combustion in condensed air, to see if the cooling power was much increased thereby, show that, as rarefaction does not diminish considerably the heat of flame in atmospherical air, so neither does condensation considerably increase it; a circumstance of great importance in the constitution of our atmosphere, which at all heights or depths, at which man can exist, still preserves the same relations to combustion.

It may be concluded from the general law, that at high temperatures, gases not concerned in combustion will have less power of preventing that operation, and likewise that steam and vapours, which require a considerable heat for their formation, will have less effect in preventing combustion, particularly of those bodies requiring low temperatures, than gases at the usual heat of the atmosphere. Thus, a very large quantity of steam is required to prevent sulphur from burning. A mixture of oxygen and hydrogen will explode by the electric spark, though diluted with five times its volume of steam; and even a mixture of air and carburetted hydrogen gas, the least explosive of all mixtures, requires a third of steam to prevent its explosion, whereas one-fifth of azote will produce that effect. These trials were made over mercury. Heat was applied to water over the mercury, and 37.5 for 100 parts $= \frac{3}{8}$, was regarded as the correction for the expansion of the gases.

We shall now treat of the effects of cooling orifices on flame. The knowledge of the cooling power of elastic *media*, in preventing the explosion of the fire-damp, led the illustrious English chemist, to those practical researches, which terminated in his grand discovery of the wire-gauze safe-lamp. The general investigation of the relation and extent of those powers, serves to elucidate the operation of wire-gauze and other tissues or systems of apertures, permeable to light and air, in intercepting flame, and confirms the views originally given of this marvellous phenomenon. We have seen that *flame* is gaseous matter, heated so highly as to be luminous, and *that* to a degree of temperature beyond the white heat of solid bodies; for air not luminous will communicate this degree of heat. When an attempt is made to pass flame through a very fine mesh of wire-gauze of the common temperature, the gauze cools each portion of the elastic matter that passes through it, so as to reduce its temperature below that degree at which it is luminous. This diminution of temperature is proportional to the smallness of the mesh, and to the mass of the metal. The power of a metallic or other tissue to prevent explosion, will depend upon the heat required to produce the combustion, as compared with that acquired by the tissue. Hence, the flame of the most inflammable substances, and of those that produce most heat in combustion, will pass through a metallic tissue, that will interrupt the flame of less inflammable substances, or those that produce little heat in combustion. Or the tissue being the same, and impermeable to all flames at common temperatures, the flames of the most combustible substances, and of those which produce most heat, will most readily pass through it, when it is heated, and each will pass through it at a different degree of temperature. In short, all the circumstances which apply to the effect of cooling mixtures upon flame, will apply to cooling perforated surfaces. Thus, the flame of phosphuretted hydrogen, at common temperatures, will pass through a tissue sufficiently large, not to be immediately choaked up by the phosphoric acid formed, and the phosphorus deposited. If a tissue, containing above 700 apertures to the square inch, be held over the flame of phosphorus or phosphuretted hydrogen, it does not transmit the flame till it is sufficiently heated to enable the phosphorus to pass through it in vapour. Phosphuretted hydrogen is decomposed by flame, and acts exactly like phosphorus. In like manner a tissue of 100 apertures to the square inch, made of a wire of $\frac{1}{60}$, will, at common temperatures, intercept the flame of a spirit-lamp, but not that of hydrogen. But when strongly heated, it no longer arrests the flame of alcohol. A tissue which will not interrupt the flame of hydrogen when red-hot, will still intercept that of olefiant gas; and a heated tissue, which would communicate explosion from a mixture of olefiant gas and air, will stop an explosion from a mixture of fire-damp, or carburetted hydrogen. The latter gas requires a considerable mass of heated metal to inflame it, or contact with an extensive heated surface. An iron wire of 1-20th of an inch, and eight inches long, red-hot, when held perpendicularly in a stream of coal gas, did not inflame it; nor did a short wire of one-sixth of an inch produce the effect, when held horizontally. But wire of the latter size, when six inches of it were red-hot, and when it was held perpendicularly, in a bottle containing an explosive mixture, so that heat was communicated successively to portions of the gas, produced its explosion.

The scale of gaseous accension, given in the first section, explains, why so fine a mesh of wire is required to hinder the explosion from hydrogen and oxygen, to pass; and why so coarse a texture and wire, controul the explosion of fire-damp. The general doctrine, indeed, of the operation of wire-gauze, cannot be better elucidated, than in its effects upon the flame of sulphur. When wire-gauze, of 600 or 700 apertures to the square inch, is held over the flame, fumes of condensed sulphur immediately come through it, and the flame is intercepted. The fumes continue for some instants, but on the increase of the heat, they diminish; and at the moment when they disappear, which is long before the gauze becomes red-hot, the flame passes; the temperature at which sulphur burns being that at which it is gaseous.

Where rapid currents of explosive mixtures, however, are made to act upon wire-gauze, it is of course much more rapidly heated: and therefore, the same mesh which arrests the flames of explosive mixtures at rest, will suffer them to pass when in rapid motion. But, by increasing the cooling surface, by diminishing the apertures in size, or increasing their depth, *all flames, however rapid their motion, may be arrested.* Precisely the same law applies to explosions acting in close vessels. Very minute apertures, when they are only few in number, will permit explosions to pass, which are arrested by much larger apertures when they fill a whole surface. A small aperture was drilled at the bottom of a wire-gauze lamp, in the cylindrical ring, which confines the gauze. This, though less than $\frac{1}{18}$ of an inch in diameter, transmitted the flame, and fired the external atmosphere, in consequence of the whole force of the explosion of the thin stratum of the mixture, included within the cylinder, driving the flame through the aperture. Had the whole ring, however, been composed of such apertures separated by wires, it would have been perfectly safe.

Nothing can demonstrate more decidedly, than these simple facts and observations, that the interruption of flame, by solid tissues, permeable to light and air, depends upon no recondite or mysterious cause, but on their cooling powers, simply considered as such. When a light, included in a cage of wire-gauze, is introduced into an explosive atmosphere of fire-damp at rest, the maximum of heat is soon obtained; the radiating power of the wire, and the cooling effect of the atmosphere, more efficient from the admixture of inflammable air, prevent it from ever arriving at a temperature equal to that of dull redness. In rapid currents of explosive mixtures of fire-damp, which heat common gauze to a higher temperature, twilled gauze, in which the radiating surface is considerably greater, and the circulation of air less, preserves an equable temperature. Indeed, the heat communicated to the wire by combustion of the fire-damp in wire-gauze lamps, is completely in the power of the manufacturer. By diminishing the apertures, and increasing the mass of metal, or the radiating surface, it may be diminished to any extent. Thick twilled gauze, made of wires $\frac{1}{40}$, 16 to the warp, and 30 to the weft, rivetted to the screw, to prevent the possibility of displacement, forms a lamp cage, which, from its flexibility, cannot be broken, and from its strength cannot be crushed, except by a very violent blow. The lamp which has been found most convenient for the miner, is that composed of a cylinder of strong wire-gauze, fastened round the flame by a screw, and in which the wick is trimmed by a wire passing through a safe aperture. Such have now been used for many years, in the most dangerous mines of England, without any accident. Whatever explosive disasters have happened since, may be imputed to the neglect, or gross and culpable mismanagement, of that infallible protector. See LAMP.

When the fire-damp is inflamed in the wire-gauze cylinders, coal dust thrown into the lamp, burns with strong flashes and scintillations. The miners were at first alarmed by an effect of this kind, produced by the dust naturally raised during the working of the coals.

But Sir H. Davy showed, by decisive experiments, that explosion could never be communicated by them, to the gas of any mine. He repeatedly threw coal dust, powdered rosin, and witch-meal, through lamps burning in more explosive mixtures, than ever occur in coal mines; and though he kept these substances floating in the explosive atmosphere, and heaped them upon the top of the lamp when it was red-hot, no explosion could ever be communicated. Phosphorus or sulphur, are the only substances which can produce explosion, by being applied to the outside of the lamp; and sulphur, to produce the effect, must be applied in large quantities, and fanned by a current of fresh air. He has even blown repeatedly, fine coal dust mixed with minute quantities of the finest dust of gunpowder, through the lamp burning in explosive mixtures, without any communication of explosion. The most timorous female might traverse an explosive coal mine, guided by the light of the double cylinder lamp, without feeling the slightest apprehension.

5. We have now arrived at the most curious of all Sir H.'s discoveries relative to fire, namely, *invisible combustion.*

On passing mixtures of hydrogen and oxygen through tubes heated below redness, steam appeared to be formed without any combustion. This led him to expose mixtures of oxygen and hydrogen to heat, in tubes, in which they were confined by fluid fusible metal. He found, that, by carefully applying a heat between the boiling point of mercury, which is not sufficient for the effect, and a heat approaching to the greatest heat that can be given without making glass luminous in darkness, the combination was effected without any violence, and without any light; and commencing with 212, the volume of steam formed at the point of combination, appeared exactly equal to that of the original gases. So that the first effect in experiments of this kind, is an expansion, afterwards a contraction, and then the restoration of the primitive volume.

When this change is going on, if the heat be quickly raised to redness, an explosion takes place. With small quantities of gas, the invisible combustion is completed in less than a minute. It is probable that the slow combination without combustion, long ago observed with respect to hydrogen and chlorine, oxygen and metals, will happen at certain temperatures with most substances that unite by heat. On trying charcoal, he found, that at a temperature which appeared to be a little above the boiling point of quicksilver, it converted oxygen pretty rapidly into carbonic acid, without any luminous appearance; and at a dull red-heat, the elements of olefiant gas combined in a similar manner with oxygen, slowly and without explosion. The effect of the slow combination of oxygen and hydrogen is not connected with their rarefaction by heat, for it took place when the gases were confined in a tube by fusible metal, rendered solid at its upper surface; and certainly as rapidly, and without any appearance of light.

As the temperature of flame has been shown to be infinitely higher than that necessary for the ignition of solid bodies, it appeared probable, that in these silent combinations of gaseous bodies, when the increase of temperature may not be sufficient to render the gaseous matters themselves luminous, yet it still might be adequate to ignite solid matters exposed to them.

Sir H. Davy had devised several experiments on this subject. He had intended to expose fine wires to oxygen and olefiant gas, and to oxygen and hydrogen, during their slow combination under different circumstances, when he was accidentally led to the knowledge of the *fact*, and at the same time to the discovery of a new and curious series of phenomena.

He was making experiments on the increase of the limits of the combustibility of gaseous mixtures of coal-gas and air, by increase of temperature. For this purpose, a small wire-gauze safe-lamp, with some fine wire of platinum fixed above the flame, was introduced into a combustible mixture, containing the maximum of coal-gas. When the inflammation had taken place in the wire-gauze cylinder, he threw in more coal-gas, expecting that the heat acquired by the mixed gas, in passing through the wire-gauze, would prevent the excess from extinguishing the flame. The flame continued for two or three seconds after the coal gas was introduced; and when it was extinguished, that part of the wire of platinum which had been hottest, remained ignited, and continued so for many minutes. When it was removed into a dark room, it was evident that there was no flame in the cylinder.

It was immediately obvious that this was the result which he had hoped to attain by other methods, and the oxygen and coal-gas in contact with the hot wire, combined without flame, and yet produced heat enough to preserve the wire ignited, and keep up their own *secret combustion*. The truth of this conclusion was proved by introducing a heated wire of platinum into a similar mixture. It immediately became ignited nearly to whiteness, as if it had been in actual combustion itself, and continued glowing for a long while. *When it was extinguished, the inflammability of the mixture was found to be entirely destroyed.* A temperature much below ignition only, was necessary for producing this curious phenomenon, and the wire was repeatedly taken out and cooled in the atmosphere till it ceased to be visibly red; yet when admitted again, it instantly became red-hot.

The same phenomena were produced with mixtures of olefiant gas and air, carbonic oxide, prussic gas, and hydrogen; and in this last case with a rapid production of water. The degree of heat could be regulated by the thickness of the wire. When of the same thickness, the wire became more ignited in hydrogen, than in mixtures of olefiant gas, and more in mixtures of olefiant gas, than in those of gaseous oxide of carbon.

When the wire was very fine, as 1-80th of an inch in diameter, its heat increased in very combustible mixtures, so as to explode them. The same wire in less combustible mixtures, continued merely bright red, or dull red, according to the nature of the mixture. In mixtures not explosive by flame within certain limits, these curious phenomena took place, whether the air or the inflammable gas was in excess. The same circumstances occurred with certain inflammable vapours. Those of ether, alcohol, oil of turpentine, naphtha, and camphor, have been tried. There cannot be a better mode of illustrating the fact, than by an experiment on the vapour of ether or of alcohol, which any person may make in a minute. Let a drop of ether be thrown into a cold glass, or a drop of alcohol into a warm one; let a few coils of wire of platinum, of the 1-60th or 1.70th of an inch, be heated at a hot poker or a candle, and let it be brought into the glass: In some part of the glass, it will become glowing, almost white-hot, and will continue so, as long as a sufficient quantity of vapour and of air, remain in the glass.

When the experiment on the slow combustion of ether is made in the dark, a pale phosphorescent light is perceived above the wire, which is of course most distinct when the wire ceases to be ignited. This appearance is connected with the formation of a peculiar acrid volatile substance, possessed of acid properties. See ACID (LAMPIC). The above experiment has been ingeniously varied by sticking loosely on the wick of a spirit lamp, a coil of fine platinum wire, about $\frac{1}{100}$ of an inch in thickness. There should be about 16 spiral turns, one-half of which should surround the wick, and the other rise above it. Having lighted the lamp for an instant, on blowing it out, the wire will become brightly ignited, and will continue to glow as long as any alcohol remains. A cylinder of camphor may be substituted for both wick and spirit. The ignition is very bright, and exhales an odoriferous vapour. With oil of turpentine, the lamp burns invisibly without igniting the wire; for a dense column of vapour is perceived to ascend from the wire, diffusing a smell by many thought agreeable. By adding essential oils in small quantities to the alcohol, various *aromas* may be made to perfume the air of an apartment. But the film of charcoal which in this case collects on the platina coil, must be removed by ignition over another spirit flame, otherwise the effect ceases after a certain time.

The chemical changes in general, produced by slow combustion, appear worthy of investigation. A wire of platinum introduced under the usual circumstances into a mixture of prussic gas (cyanogen), and oxygen in excess, became ignited to whiteness, and the yellow vapours of nitrous acid were observed in the mixture. In a mixture of olefiant gas, non-explosive from the excess of inflammable gas, much carbonic oxide was formed. Platinum and palladium, metals of low conducting powers, and small capacities for heat, alone succeed in producing the above phenomena. A film of carbon or sulphur deprives even these metals of this property. Thin laminæ of the metals, if their form admits of a free circulation of air, answer as well as fine wires; and a large surface of platinum may be made red-hot in the vapour of ether, or in a combustible mixture of coal gas and air.

Sir H. Davy made an admirable practical application of these new facts. By hanging some coils of fine platinum wire, or a fine sheet of platinum or palladium, above the wick of the safe-lamp in the wire-gauze cylinder, he has supplied the coal-miner with light in mixtures of fire-damp no longer explosive. Should the flame be extinguished by the quantity of fire-damp, the glow of the platinum will continue to guide him; and by placing the lamp in different parts of the gallery, the relative brightness of the wire will show the state of the atmosphere in these parts Nor can there be any danger with respect to respiration wherever the wire continues ignited; for even this phenomenon ceases, when the foul air forms about $\frac{2}{5}$ of the volume of the atmosphere.

Into a wire-gauze safe-lamp, a small cage made of fine wire of platinum, of 1-70th of an inch in thickness, was introduced, and fixed by means of a thick wire of platinum, about 2 inches above the lighted wick. This apparatus was placed in a large receiver, in which, by means of a gas-holder, the air could be contaminated to any extent with coal-gas. As soon as there was a slight admixture of coal-gas, the platinum became ignited. The ignition continued to increase till the flame of the wick was extinguished, and till the whole cylinder became filled with flame. It then diminished. When the quantity of coal-gas was increased so as to extinguish the flame, the cage of platinum, at the moment of the extinction, became white hot, presenting a most brilliant light. By increasing the quantity of the coal-gas still further, the ignition of the platinum became less vivid. When its light was barely sensible, small quantities of air were admitted, and it speedily increased. By regulating the admission of coal-gas and air, it again became white-hot, and soon after lighted the flame in the cylinder, which as usual, by the addition of more atmospheric air, rekindled the flame of the wick.

This beautiful experiment has been very often repeated, and always with the same results. When the wire for the support of the cage, whether of platinum, silver, or copper, was very thick, it retained sufficient heat, to enable the fine platinum wire to rekindle in a proper mixture *half a minute* after its light had been entirely destroyed, by an atmosphere of pure coal-gas. The phenomenon of the ignition of the platinum, takes place feebly in a mixture consisting of two of air and one of coal-gas; and brilliantly in a mixture consisting of three of air and one of coal-gas. The greater the quantity of heat produced, the greater may be the quantity of the coal-gas, so that a large tissue of wire made white-hot, will burn in a more inflammable mixture (that is, containing more inflammable gas), than one made red-hot. If a mixture of three parts of air and one of fire-damp, be introduced into a bottle, and inflamed at its point of contact with the atmosphere, it will not explode, but will burn like a pure inflammable substance. If a fine wire of platinum, coiled at its end, be slowly passed through the flame, it will continue ignited in the body of the mixture, and the same gaseous matter will be found to be *inflammable*, and to be a *supporter* of combustion. When a large cage of wire of platinum is introduced into a very small safe-lamp, even explosive mixtures of fire-damp are burned without flame; and by placing any cage of platinum in the bottom of the lamp round the wick; the wire is prevented from being smoked. Care should be taken of course, that no filament of the platinum protrude through the wire-gauze. It is truly wonderful, that a slender tissue of platinum, which does not cost one shilling, and which is imperishable, should afford in the dark and dangerous recesses of a coal mine, a most *brilliant light*, perfectly safe, in atmospheres in which the flame of the safety-lamp is extinguished; and which glows in every mixture of carburetted hydrogen gas that is respirable. When the atmosphere becomes again explosive, the *flame* is relighted.

It is no less surprising, that thus also we can burn any inflammable vapour, either with or without flame, at pleasure, and make a slender wire consume it, either with a white or red heat.

6. We shall conclude the subject of combustion with some practical inferences.

The facts detailed on insensible combustion, explain why so much more heat is obtained from fuel, when it is burned quickly than slowly; and they show, that in all cases the temperature of the acting bodies should be kept as high as possible, not only because the general increment of heat is greater, but likewise because those combinations are prevented, which, at lower temperatures, take place without any considerable production of heat. Thus, in the argand lamp, and in the best fire-places, the increase of effect does not depend merely upon the rapid current of air, but likewise upon the heat preserved by the arrangement of the materials of the chimney, and communicated to the matters entering into inflammation.

These facts likewise explain, the source of the great error, into which Mr. Dalton has fallen in estimating the heat given out in the combustion of charcoal; and they indicate methods by which temperature may be increased, and the limits to certain methods. Currents of flame can never raise the heat of bodies exposed to them, higher than a certain degree, that is, their own temperature. But by compression, there can be no doubt, that the heat of flames from pure supporters and combustible matter may be greatly increased, probably in the ratio of their compression. In the blow-pipe of oxygen and hydrogen, the maximum of temperature is close to the aperture from which the gases are disengaged, that is, where their density is greatest. Probably a degree of temperature far beyond any that has yet been attained, may be produced by throwing the flame from compressed oxygen and hydrogen into the voltaic arc, and thus combining the two most powerful agents for increasing temperature.

The nature of the light, and form of flames, can now be clearly understood. When in flames pure *gaseous* matter is burnt, the light is extremely feeble. The density of a common flame, is proportional to the quantity of solid charcoal, the first deposited and afterwards burned. The form of the flame is conical, because the greatest heat is in the centre of the explosive mixture. In looking stedfastly at flame, the part where the combustible matter is volatilized is seen, and it appears dark, contrasted with the part in which it begins to burn; that is, where it is so mixed with air as to become explosive. The heat diminishes towards the top of the flame, because in this part the quantity of oxygen is least. When the wick increases to a considerable size, from collecting charcoal, it cools the flame by radiation, and prevents a proper quantity of air from mixing with its central part; in consequence, the charcoal thrown off from the top of the flame is only red-hot, and the greater part of it escapes unconsumed.

The intensity of the *light* of flames in the atmosphere is increased by condensation and diminished by rarefaction, apparently in a higher ratio than their *heat:* More particles capable of emitting light exist in the denser atmospheres, and yet most of these particles in becoming capable of emitting light, absorb heat, which could not be the case in the condensation of a pure supporting medium.

The facts on rarefaction of inflammable gases show, that the luminous appearances of shooting stars and meteors, cannot be owing to any inflammation of *elastic* fluids, but must depend on the ignition of *solid* bodies. Dr. Halley calculated the height of a meteor at ninety miles, and the great American meteor which threw down showers of stones, was estimated at seventeen miles high. The velocity of motion of these bodies must in all cases be immensely great, and the heat produced by the compression of the most rarified air, from the velocity of motion, must be probably sufficient to ignite the mass. All the phenomena may be explained, if *falling* stars be supposed to be small solid bodies moving around the earth in very eccentric orbits, which become ignited only when they pass with immense velocity through the upper regions of the atmosphere; and if the *meteoric bodies* which throw down stones with explosions, be supposed to be similar bodies which contain either combustible or elastic matter.

When the *common* electrical or *voltaic* electrical spark is taken in rare air, the light is considerably diminished, as well as the heat. Yet, in a receiver that contained air 60 times rarer than that of the atmosphere, a piece of wire of platinum, placed by Sir H. Davy in the centre of the luminous arc, produced by the great voltaic apparatus of the Royal Institution, became white-hot; and that this was not owing to the electrical conducting powers of the platinum, was proved by repeating the experiment with a filament of glass, which instantly fused in the same position. It is evident from this, that electrical heat and light may appear in atmospheres, in which the flame of combustible bodies could not exist; and the fact is interesting from its possible application in explaining the phenomena of the *Aurora Borealis* and *Australis*.

Finally, we may establish it as an axiom, that combustion is not the great phenomenon of chemical nature; but an adventitious accidental accessory to chemical combination, or decomposition; that is, to the internal motions of the particles of bodies, tending to arrange them in a new chemical constitution.

Several cases of death, from spontaneous combustion of the body, are on record. The appearances resemble those which would be produced by phosphuretted hydrogen.*

Comptonite. A new mineral, found in drusy cavities, in ejected masses, on Mount Vesuvius. It occurs crystallized, in straight four-sided prisms, which are usually truncated on their lateral edges, so as to form eight-sided prisms, terminated with flat summits. Transparent, or semi-transparent. Gelatinizes with acids. It is sometimes accompanied with acicular Arragonite. It was first brought to this country by Lord Compton, in 1818.

* **Concretions (Morbid).** Solid deposites, formed by disease in the soft parts, or in the cavities of animal bodies. The former are usually called *ossifications*, as they seem to consist of calcareous phosphate. They are named, according to the part in which they are deposited, pineal, salivary, pulmonary, pancreatic, hepatic, prostatic, gouty. Deposites in *cavities* are generally styled calculi, from their resemblance to pebbles. These are intestinal, gall-stones or biliary, renal, and urinary. *See the respective articles.**

* **Congelation.** In addition to the methods pointed out under **Caloric**, for effecting artificial congelation, we shall here describe the elegant mode by the air-pump, recently perfected by Professor Leslie.

The very ingenious Dr. Cullen seems to have been the first who applied the vacuum of an air-pump to quicken the evaporation of liquids, with a view to the abstraction of heat, or artificial congelation. In the year 1755, he plunged a full phial of ether into a tumbler of water, and on placing it under the receiver, and exhausting the air, the ether boiled, and the surrounding water froze.

In the year 1777, Mr. Edward Nairne, a very eminent London optician, published in the Transactions of the Royal Society, " an account of some experiments made with an air-pump." After stating that at a certain point of rarefaction, the moisture about the pump furnished an atmosphere of vapour, which affected his comparative results with the mercurial gauge and pear guage, he says, "I now put some sulphuric acid into the receiver, as a means of trying to make the remaining contents of the receiver, when exhausted as much as possible, to consist of permanent air only, *unadulterated with vapour*." He was thus enabled by this *artificial dryness* to exhibit certain electrical phenomena to great advantage. The next step which Mr. Nairne took, was to produce *artificial cold* by the air-pump. "Having lately received from my friend Dr. Lind," he says, " some ether prepared by the ingenious Mr. Woulfe, I was very desirous to try whether I could produce any considerable degree of cold by the evaporation of ether under a receiver whilst exhausting." Accordingly he succeeded in sinking a thermometer, whose bulb was from time to time dipped into the ether in vacuo, 103° below 56°, the temperature of the apartment. Mr. Nairne made no attempt to condense the vapour in vacuo by chemical means, and thus to favour its renewed formation from the liquid surface; which I consider to be the essence of Professor Leslie's capital improvement, on Cullen's plan of artificial refrigeration. After Nairne's removing the vapour of water by sulphuric acid to produce artificial *dryness*, there was indeed but a slight step to the production of artificial *cold*, by the very same arrangement; but still this step does not appear to have been attempted by any person from the year 1777 till 1810, when Professor Leslie was naturally led to make it, by the train of his researches on evaporation and hygrometry.

The extreme rapidity of evaporation in vacuo, may be inferred from Dr. Robison's position, that all liquids boil in it, at a temperature 120° to 125° lower than their usual boiling point in the atmosphere. Could we find a liquid or solid substance which would rapidly imbibe alcohol, ether or sulphuret of carbon, we would probably be able to effect reductions of temperature prodigiously greater than any hitherto reached. Water, however, has no doubt one advantage, in the superior latent heat of its vapour, which must compensate in a considerable degree for its inferior rapidity of vaporization.

In the month of June 1810, Professor Leslie having introduced a surface of sulphuric acid under the receiver of an air-pump, and also a watch-glass filled with water, he found that after a few strokes of the pump, the water was converted into a solid cake of ice, which being left in the rarefied medium, continued to evaporate, and after the interval of about an hour, totally disappeared. When the air has been rarefied 250 times, the utmost that under such circumstances can perhaps be effected, the surface of evaporation is cooled down 120° Fahrenheit in winter, and would probably, from more copious evaporation and condensation, sink near 200° in summer. If the air be rarefied only 50 times, a depression of 80°, or even 100°, will be produced.

We are thus enabled by this elegant combination, to freeze a mass of water in the hottest weather, and to keep it frozen, till it gradually wastes away, by a continued but invisible process of evaporation. The only thing required is, that the surface of the acid should approach tolerably near to that of the water, and should have a greater extent; for otherwise the moisture would exhale more copiously than it could be transferred and absorbed, and consequently the dryness of the rarefied medium would become reduced, and its evaporating energy essentially impaired. The acid should be poured to the depth of perhaps half an inch, in a broad flat dish, which is covered by a receiver of a form nearly hemispherical; the water exposed to congelation may be contained in a shallow cup, about half the width of the dish, and having its rim supported by a narrow porcelain ring, upheld above the surface of the acid by three slender feet. It is of consequence that the water should be insulated as much as possible, or should present only a humid surface to the contact of the surrounding medium; for the dry sides of the cup might receive, by radiation from the external air, such accessions of heat, as greatly to diminish, if not to counteract the refrigerating effects of evaporation. This inconvenience is in a great measure obviated, by investing the cup with an outer case, at the interval of about half an inch. If both the cup and its case consist of glass, the process of congelation is viewed most completely; yet when they are formed of a bright metal, the effect appears, on the whole, more striking. But the preferable mode, and that which prevents any waste of the powers of refrigeration, is to expose the water in a saucer of porous earthen ware. At the instant of congelation, a beautiful network of icy spiculæ pervades the liquid mass.

The disposition of the water to fill the receiver with vapour, will seldom permit even a good air-pump to produce greater rarefaction than that indicated by 3-10ths of an inch of mercury, beneath the barometrical height, at the time. But every practical object may be obtained by more moderate rarefactions, and a considerable surface of acid. The process goes on more slowly, but the ice is very solid, especially if the water have been previously purged of its air by distillation, or boiling for a considerable time. If we use a receiver, with a sliding wire passing down from its top through a collar of leathers, and attach to it a disc of glass; on applying this to the surface of the water cup, we may instantly suspend the process of congelation; and raising the disc as suddenly, permit the advancement of the process.

In exhibiting the different modifications of this system of congelation to my pupils, I have been accustomed for many years to recommend the employment of a series of cast-iron plates, attachable by screws and stop-cocks to the air-pump. Each iron disc has a receiver adapted to it. Thus, we may with one air-pump, successively put any number of freezing processes in action. A cast-iron drum of considerable dimensions being filled with steam, by heating a small quantity of water in it, will sufficiently expel the air for producing the requisite vacuum. When it is cooled by affusion of water, one of the above transferrer plates being attached to the stop-cock on its upper surface, would easily enable us, without any air-pump, to effect congelation by means of sulphuric acid, in the attenuated atmosphere. Suppose the capacity of the receiver, to be 1-60th of the iron cylinder; an aeriform rarefaction to this degree would be effected in a moment by a turn of the stop-cock; and on its being returned, the moisture below would be cut off, and the acid would speedily condense the small quantity of vapour which had ascended.

This cheap and powerful plan was publicly recommended by me upwards of ten years ago, when I had a glass model of it made for class illustration.

The combined powers of rarefaction, vaporization, and absorption, are capable of effecting the congelation of quicksilver. If this metal, contained in a hollow pear-shaped piece of ice, be suspended by cross threads near a broad surface of sulphuric acid, under a receiver, on urging the rarefaction, it will become frozen, and may be kept in the solid state for several hours. Or otherwise, having introduced mercury into the large bulb of a thermometer, and attached the stem to the sliding rod of the receiver, place this over the sulphuric acid, and water cup on the air-pump plate. After the air has been rarefied about 50 times, let the bulb be dipped repeatedly into the very cold but unfrozen water, and again drawn up about an inch. In this way it will become incrusted with successive coats of ice, to the twentieth of an inch thick. The cup of water being now withdrawn from the receiver, the pendent icicle cut away from the bulb, and the surface of the ice smoothed with a warm finger, the receiver is again to be replaced, and the bulb being let down within half an inch of the acid, the exhaustion must be pushed to the utmost. When the syphon-gauge arrives at the tenth of an inch, the icy crust opens with fissures, and the mercury having gradually descended in the tube, till it reach its point of congelation, or 39° below zero, sinks by a sudden contraction almost into the cavity of the bulb. The apparatus being now removed, and the ball speedily broken, the metal appears a solid shining mass, that will bear the stroke of a hammer. A still greater degree of cold may be produced, by applying the same process to cool the atmosphere, which surrounds the receiver.

When the acid has acquired one-tenth of water, its refrigerating power is diminished only one-hundredth. When the quantity of moisture is equal to one-fourth of the concentrated acid, the power of generating cold is reduced by a twentieth; and when the dilution is one-half, the cooling powers become one-half or probably less. Sulphuric acid is hence capable of effecting the congelation of more than twenty times its weight of water, before it has imbibed nearly its own bulk of that liquid, or has lost about one-eighth of its refrigerating power. The acid should then be removed, and reconcentrated by heat.

The danger of using a corrosive acid in unskilful hands, may be obviated by using oatmeal, desiccated nearly to brownness before a kitchen-fire, and allowed to cool in close vessels. With a body of this, a foot in diameter, and an inch deep, Professor Leslie froze a pound and a quarter of water, contained in a hemispherical porous cup. Muriate of lime in ignited porous pieces, may also be employed as an absorbent. Even mouldering trap or whinstone, has been used for experimental illustration with success.

By the joint operation of radiation and evaporation from the surface of water, the natives of India are enabled to procure a supply of ice, when the temperature of the air is many degrees *above* the freezing point. Not far from Calcutta, in large open plains, three or four excavations are made in the ground, about 30 feet square, and 2 feet deep, the bottom of which is covered to the thickness of nearly a foot with sugar canes, or dried stalks of Indian corn. On this bed are placed rows of small unglazed earthen pans, about an inch and a quarter deep, and somewhat porous. In the dusk of the evening, during the months of December, January, and February, they are filled with soft water, previously boiled and suffered to cool. When the weather is very fine and clear, a great part of the water becomes frozen during the night. The pans are regularly visited at sunrise, and their contents emptied into baskets which retain the ice. These are now carried to a conservatory made by sinking a pit 14 or 15 feet deep, lined with straw under a layer of coarse blanketing. The small sheets of ice are thrown down into the cavity, and rammed into a solid mass. The mouth of the pit is then closed up with straw and blankets, and sheltered by a thatched roof.

For some additional facts, on this interesting subject, see the sequel of the article Dew.*

*Conite. An ash or greenish-gray coloured mineral, which becomes brown on exposure to the air. It is massive or stalactitic, is dull internally, and has a small grained uneven fracture. It is brittle; sp. gr. 2.85. It dissolves in nitric acid, with slight effervescence, and blackens without fusing before the blow-pipe. Its constituents are 67.5 carbonate of magnesia, 28 carbonate of lime, 3.5 oxide of iron, and 1 water. It is found in the Meissner trap hill in Hessia, in Saxony, and Iceland. Dr. Macculloch has given the name *Conite* to a pulverulent mineral, as fusible as glass, into a transparent bead, which he found in Mull and Glenfarg, in the trap hills of Kilpatrick, and the Isle of Sky.*

Copal, improperly called gum copal, is a hard, shining, transparent, citron-coloured, odoriferous, concrete juice of an American tree, but which has neither the solubility in water common to gums, nor the solubility in alcohol common to resins, at least in any considerable degree. By these properties it resembles amber. It may be dissolved by digestion in linseed oil, rendered drying by quicklime, with a heat very little less than sufficient to boil or decompose the oil. This solution, diluted with oil of turpentine, forms a beautiful transparent varnish, which, when properly applied, and slowly dried, is very hard, and very durable. This varnish is applied to snuff-boxes, tea-boards, and other utensils. It preserves and gives lustre to paintings, and greatly restores the decayed colours of old pictures, by filling up the cracks, and rendering the surfaces capable of reflecting light more uniformly.

Mr. Sheldrake has found, that camphor has a powerful action on copal; for if powdered copal be triturated with a little camphor, it softens, and becomes a coherent mass; and camphor added either to alcohol or oil of turpentine, renders it a solvent of copal. Half an ounce of camphor is sufficient for a quart of oil of turpentine, which should be of the best quality; and the copal, about the quantity of a large walnut, should be broken into very small pieces, but not reduced to a fine powder. The mixture should be set on a fire so brisk as to make the mixture boil almost immediately; and the vessel Mr. S. recommends to be of tin or other metal, strong, shaped like a wine bottle with a long neck, and capable of holding two quarts. The mouth should be stopped with a cork, in which a notch is cut to prevent the vessel from bursting. It is probably owing to the quantity of camphor it contains, that oil of lavender is a solvent of copal. Camphor and alcohol dissolve copal still more readily than camphor and oil of turpentine.

Lewis had observed, that solution of ammonia enabled oil of turpentine to dissolve copal; but it requires such nice management of the fire that it seldom succeeds completely.

* In the 51st volume of Tilloch's Magazine, Mr. Cornelius Varley states, that a good varnish may be made by pouring upon the purest lumps of copal, reduced to a fine mass, in a mortar, colourless spirits of turpentine, to about one-third higher than the copal, and triturating the mixture occasionally in the course of the day. Next morning it may be poured off into a bottle for use. Successive portions of oil of turpentine may thus be worked with the same copal mass. Camphorated oil of turpentine, and oil of spike-lavender, are also recommended as separate solvents without trituration. The latter, however, though very good for drawings or prints, will not do for varnishing pictures, as it dissolves the paint underneath, and runs down while drying.*

Copper is a metal of a peculiar reddish-brown colour; hard, sonorous, very malleable and ductile; of considerable tenacity, and of a specific gravity from 8.6 to 8.9. At a degree of heat far below ignition, the surface of a piece of polished copper becomes covered with various ranges of prismatic colours, the red of each order being nearest the end which has been most heated; an effect which must doubtless be attributed to oxidation, the stratum of oxide being thickest where the heat is greatest, and growing gradually thinner and thinner towards the colder part. A greater deree of heat oxidizes it more rapidly, so that it contracts thin powdery scales on its surface, which may be easily rubbed off; the flame of the fuel becoming at the same time of a beautiful bluish-green colour. In a heat, nearly the same as is necessary to melt gold or silver, it melts and exhibits a bluish-green flame; by a violent heat it boils, and is volatilized partly in the metallic state.

Copper rusts in the air; but the corroded part is very thin, and preserves the metal beneath from farther corrosion.

* We have two oxides of copper, the black, procurable by heat, or by drying the hydrated oxide, precipitated by potash from the nitrate. It consists of 8 copper + 2 oxygen. It is a deutoxide. The protoxide is obtained by digesting a solution of muriate of copper with copper turnings, in a close phial. The colour passes from green to dark brown, and gray crystalline grains are deposited. The solution of these yields, by potash, a precipitate of an orange colour, which is the protoxide. It consists of 8 copper + 1 oxygen. Protoxide of copper has been lately found by Mr. Mushet, in a mass of copper, which had been exposed to heat for a considerable time, in one of the melting furnaces of the mint under his superintendence.

Copper, in filings, or thin laminæ, introduced into chlorine, unites with flame into the chloride, of which there are two varieties; the protochloride, a fixed yellow substance, and the deutochloride, a yellowish-brown pulverulent sublimate. 1. The crystalline grains deposited from the above muriatic solution, are *protochloride*. The protochloride is conveniently made by heating together two parts of corrosive sublimate, and one of copper filings. An amber-coloured translucent substance, first discovered by Boyle, who called it resin of copper, is obtained. It is fusible at a heat just below redness; and in a close vessel, or a vessel with a narrow orifice, is not decomposed or sublimed by a strong red heat. But if air be admitted it is dissipated in dense white fumes. It is insoluble in water. It effervesces in nitric acid. It dissolves silently in muriatic acid, from which it may be precipitated by water. By slow cooling of the fused mass Dr. John Davy obtained it crystallized, apparently in small plates, semitransparent, and of a light yellow colour. It consists, by the same ingenious chemist, of

Chlorine, 36	or 1 prime =	4.45	35.8
Copper, 64	or 1 prime	8.00	64.2
100		12.45	100.0

2. *Deutochloride* is best made by slowly evaporating to dryness, at a temperature not much above 400° Fahr. the deliquescent muriate of copper. It is a yellow powder. By absorption of moisture from the air, it passes from yellow to white, and then green, reproducing common muriate. Heat converts it into protochloride, with the disengagement of chlorine. Dr. Davy ascertained the chemical constitution of both these compounds, by separating the copper with iron, and the chlorine by nitrate of silver. The deutochloride consists

of Chlorine, 53	2 primes	8.9	52.7
Copper, 47	1 do.	8.0	47.3
100		16.9	100 0

The *iodide* of copper is formed by dropping aqueous hydriodate of potash into a solution of any cupreous salt. It is an insoluble dark brown powder.

Phosphuret of copper is made by projecting phosphorus into red-hot copper. It is of a white colour, harder than iron, pretty fusible, but not ductile. Its sp. gr. is 7.12. It crystallizes in four-sided prisms. Proust, its discoverer, says it consists of 20 phosphorus + 80 copper. 1.5 or 3.0 phosphorus + 8.0 copper, form the equivalent proportions by theory. Heat burns out the phosphorus, and scorifies the copper.

Sulphuret of copper is formed by mixing together eight parts of copper filings, and two of sulphur, and exposing the mixture to a gentle heat. Whenever the sulphur is raised a little above its melting temperature, combustion suddenly pervades the whole mass with explosive violence.

Ignition, with reciprocal saturation, constitutes a true combustion, of which every character is here. And since the experiment succeeds perfectly well *in vacuo*, or in azote, we are entitled to consider sulphur as a true supporter of combustion, if this name be retained in chemistry; a name indicating, what no person can prove, that one of the combining bodies is a mere supporter, and the other a mere combustible. Combustion is, on the contrary, shown by this beautiful experiment, to be independent of those bodies vulgarly reckoned supporters. Indeed, sulphur bears to copper the same electrical relation, that oxygen and chlorine bear to this metal. Hence sulphur is at once a supporter and combustible, in the fullest sense; a fact fatal to this technical distinction, since one body cannot be possessed of diametrically opposite qualities.

When a disc of copper, with an insulated handle, is made to touch a disc of sulphur, powerful electrical changes ensue; and at a higher temperature we see, that the reciprocal attractive forces, or the corpuscular movements which accompany energetic affinity, excite the phenomena of combustion. To say that one of the combining bodies contains a latent magazine of heat and light, to feed the flame of the other body, is an hypothesis altogether destitute of proof, which should therefore have no place in one of the exact sciences, far less be made the groundwork of a chemical system

Sulphuret of copper consists, according to Berzelius, of very nearly 8 copper + 2 sulphur. We may regard it as containing a prime of each constituent.*

The sulphuric acid, when concentrated and boiling, dissolves copper. If water be added to this, it forms a blue solution of copper, which, by evaporation, affords blue crystals, that require about four times their weight of water to dissolve them.

The solutions of copper in sulphuric acid are slightly caustic. Magnesia, lime, and the fixed alkalis, precipitate the metal from them in the form of oxide. Volatile alkali precipitates all the solution of copper, but redissolves the oxide, and produces a deep blue colour. There are certain mineral waters in Hungary, Sweden, Ireland, and in various parts of England, which contain sulphate of copper, and from which it is precipitated by the addition of pieces of old iron.

Nitric acid dissolves copper with great rapidity, and disengages a large quantity of nitrous gas. Part of the metal falls down in the form of an oxide; and the filtrated or decanted solution, which is of a much deeper blue colour than the sulphuric solution, affords crystals by slow evaporation. This salt is deliquescent, very soluble in water, but most plentifully when the fluid is heated. Its solution, exposed to the air in shallow vessels, deposites an oxide of a green colour. Lime precipitates the metal of a pale blue, fixed alkalis of a bluish-white. Volatile alkali throws down bluish flocks, which are quickly redissolved, and produce a lively blue colour in the fluid.

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* The saline combinations of copper were formerly called *sales veneris*, because Venus was the mythological name of copper. They have the following general characters: 1. They are mostly soluble in water, and their solutions have a green or blue colour, or acquire one of these colours on exposure to air. 2. Ammonia added to the solutions, produces a deep blue colour. 3. Ferroprussiate of potash gives a reddish-brown precipitate, with cupreous salts. 4. Gallic acid gives a brown

precipitate. 5. Hydrosulphuret of potash gives a black precipitate. 6. A plate of iron immersed in these solutions throws down metallic copper, and very rapidly if there be a slight excess of acid. The protoxide of copper can be combined with the acids only by very particular management. All the ordinary salts of copper have the peroxide for a base.

Acetate of copper. The joint agency of air and acetic acid, is necessary to the production of the cupreous acetates. By exposing copper plates to the vapours of vinegar, the bluish-green *verdigris* is formed, which by solution in vinegar constitutes acetate of copper. This salt crystallizes in four-sided truncated pyramids. Its colour is a fine bluish-green. Its sp. gr. is 1.78. It has an austere metallic taste; and swallowed, proves a violent poison. Boiling water dissolves one-fifth of the salt, of which it deposites the greater part on cooling. It is soluble also in alcohol. It effloresces by exposure to air. By heat, in a retort, it yields acetic acid, and pyro-acetic spirit. Sulphuretted hydrogen throws down the copper from solutions of this salt, in the state of sulphuret. Dr. Thomson gives the following account of its composition: "According to Proust, the acetate of copper is composed of

61 acid and water,
39 oxide,

100

"If we suppose it a compound of 1 atom acid, 1 atom oxide, and 8 atoms water, its constituents will be

Acetic acid,	25.12
Peroxide of copper,	39.41
Water,	35.47
	100.00

"I consider these to be its true constituents." Here we have an amusing specimen of atomical reasoning; beginning the syllogism with a supposition, and concluding it with a certainty. I had occasion to analyze this salt with some care about two years ago, and found it to consist by experiment of

	Exper.			*Theory.*
Acetic acid,	52.0	2 atoms	13.26	51.98
Perox. of cop.	39.6	1 do.	10.00	39.20
Water,	8.4	1 do.	2.25	8.82
	100.0		25.51	100.00

Instead of 35½ per cent of water, which the Doctor pitches on at random, it has not 9; and instead of only 25 of acid, it really contains more than double that quantity. The crystallized salt is a *binacetate of copper*.

The subacetate of Proust, obtained by dissolving verdigris in water, is said to consist of acid and water, 37
Oxide, 63

The proportion of 40 acid + 60 oxide, is that of 1 atom of each, to use the hypothetical term. Now Proust's experiments seem to leave uncertainty to the amount of that difference. This salt should be called probably the *acetate*. Proust's insoluble part of verdigris will become the *subacetate*. This constitutes 44 per cent, and the other 56. But the proportions will fluctuate; and an intermixture of carbonate may be expected occasionally.

Arseniate of copper presents us with many sub-species which are found native. The arseniate may be formed artificially by digesting arsenic acid on copper, or by adding arseniate of potash to a cupreous saline solution.

1. *Obtuse octohedral arseniate*, consisting of two four-sided pyramids, applied base to base, of a deep sky-blue or grass-green colour. Their sp. gr. is 2.88. They consist, according to Chenevix, of 14.3 acid + 50 brown oxide + 35.7 water. 2. *Hexahedral arseniate* is found in fine six-sided laminæ, divisible into thin scales. Its colour is a deep emerald-green; and its sp. gr. 2.548. It consists, by Vauquelin, of 43 acid + 39 oxide + 18 water. When arseniate of ammonia is poured into nitrate of copper, this variety precipitates in small blue crystals. 3. *Acute octohedral arseniate*, composed of two four-sided pyramids, applied base to base, and sometimes in rhomboidal prisms, with dihedral summits. It consists of 29 acid + 50 oxide + 21 water. The last ingredient is sometimes wanting. 4. *Trihedral arseniate* occurs also in other forms. Colour bluish-green. It consists, by Chenevix, of 30 acid + 54 oxide + 16 water. 5. *Superarseniate*. On evaporating the supernatant solution in the second variety artificially made, and adding alcohol, M. Chenevix obtained a precipitate in small blue rhomboidal crystals. They were composed of 40.1 acid + 35.5 oxide + 24.4 water. The following is a general table of the composition of these arseniates:—

	Acid.	*Oxide.*	*Water.*
1.	1.00	3.70	2.50
2.	1.00	2.76	1.00
3.	1.00	1.72	0.70
4.	1.00	1.80	0.53
5.	1.00	0.88	0.60

It will require the atomical couch of Procrustes, to accommodate these proportions to the number 14.5, recently pitched upon for arsenic acid by Dr. Thomson.

Arsenite of copper, called Scheele's green, is prepared by the old prescription of mixing a solution of 2 parts of sulphate of copper in 44 of water, with a solution of 2 parts of potash of commerce, and 1 of pulverized arsenious acid, also in 44 of water. Both solutions being warm, the first is to be gradually poured into the second. The grass-green insoluble precipitate is to be well washed with water.

Carbonate of copper. Of this compound there are three native varieties, the green, the blue, and the anhydrous. According to Mr. R. Phillips, the following is the order of their composition:—

	1st.	*2d.*	*3d.*
Carbonic acid,	2.75	11.00	2.75
Deutox. copper,	10.00	30.00	10.00
Water,	1.125	2.25	0.00
Weights of primes,	13.875	43.25	12.75

The artificial carbonate, obtained by Proust, on adding an alkaline carbonate to a solution of the nitrate of copper, is the same with the second kind.

Chlorate of copper is a deflagrating deliquescent green salt.

Fluate of copper is in small blue-coloured crystals.

Hydriodate of copper is a grayish-white powder.

Protomuriate of copper has already been described in treating of the chlorides.

Deutomuriate of copper, formed by dissolving the deutoxide in muriatic acid, or by heating muriatic acid on copper filings, yields by evaporation crystals of a grass-green colour, in the form of rectangular parallelopipeds. Their sp. gr. is 1.68. They are caustic, very deliquescent, and of course very soluble in water. According to Berzelius, it consists of

acid,	40.2
Deutoxide,	59.8
	100.0

The *ammonia-nitrate* evaporated, yields a fulminating copper. Crystals of nitrate, mixed with phosphorus, and struek with a hammer, detonate. When pulverized, then slightly moistened, and suddenly wrapt up firm, in tin-foil, the nitrate produces an explosive combustion. The nitrate seems to consist of a prime of acid + a prime of deutoxide, besides water of crystallization.

Subnitrate of copper is the blue precipitate, occasioned by adding a little potash to the neutral nitric solution.

Nitrite of copper is formed by mixing nitrite of lead with sulphate of copper.

The *sulphate* or blue vitriol of commerce is a bisulphate. Its sp. gr. is 2.2. It consists of

Acid,	31.38	2 primes,	10.0	32.0
Oxide,	32.32	1 do.	10.0	32.0
Water,	36.30	10 do.	11.25	36.0
	100.00		31.25	100.0

A mixed solution of this sulphate and sal ammoniac, forms an ink, whose traces are invisible in the cold, but become yellow when heated; and vanish again as the paper cools.

A neutral sulphate of copper may be formed by saturating the excess of acid with oxide of copper. It crystallizes in four-sided pyramids, separated by quadrangular prisms.

Mr. Proust formed a subsulphate by adding a little pure potash to a solution of the last salt. A green-coloured precipitate falls.

Protosulphite of copper is formed by passing a current of sulphurous acid gas through the deutoxide of copper diffused in water. It is deprived of a part of its oxygen, and combines with the acid. The sulphate, simultaneously produced, dissolves in the water; while the sulphite forms small red crystals, from which merely long ebullition in water expels the acid.

Sulphite of potash and copper is made by adding the sulphite of potash to nitrate of copper. A yellow flocculent precipitate, consisting of minute crystals, falls.

Ammonia-sulphate of copper is the salt formed by adding water of ammonia to solution of the bisulphate. It consists, according to Berzelius, of 1 prime of the cupreous, and 1 of the ammoniacal sulphate, combined together; or 20.0 + 7.13 + 14.625 of water.

Subsulphate of ammonia and copper is formed by adding alcohol to the solution of the preceding salt, which precipitates the subsulphate. It is the *cuprum ammoniacum* of the pharmacopœia. According to Berzelius, it consists of

Acid,	32.25	or nearly 2	primes,
Deutox. of copper,	34.00	1	do.
Ammonia,	26.40	4	do.
Water,	7.35	2	do.
	100.00		

Sulphate of potash and copper is formed by digesting bisulphate of potash on the deutoxide or carbonate of copper. Its crystals are greenish-coloured, flat parallelopipedons. It seems to consist of 2 primes of sulphate of potash + 1 prime of bisulphate of copper + 12 of water.

The following acids, antimonic, antimonious, boracic, chromic, molybdic, phosphoric, tungstic, form insoluble salts with deutoxide of copper. The first two are green, the third is brown, the fourth and fifth green, and the sixth white. The benzoate is in green crystals, sparingly soluble. The oxalate is also green. The binoxalates of potash and soda, with oxide of copper, give triple salts, in green needle-form crystals. There are also ammonia-oxalates in different varieties. Tartrate of copper forms dark bluish-green crystals. Cream-tartrate of copper is a bluish-green powder, commonly called Brunswick Green.

To obtain pure copper for experiments,

we precipitate it in the metallic state, by immersing a plate of iron in a solution of the deutomuriate. The pulverulent copper must be washed with dilute muriatic acid.*

In the wet way Brunswick or Friezland green is prepared by pouring a saturated solution of muriate of ammonia over copper filings or shreds in a close vessel, keeping the mixture in a warm place, and adding more of the solution from time to time, till three parts of muriate and two of copper have been used. After standing a few weeks, the pigment is to be separated from the unoxidized copper, by washing through a sieve; and then it is to be well washed, and dried slowly in the shade. This green is almost always adulterated with ceruse.

This metal combines very readily with gold, silver, and mercury. It unites imperfectly with iron in the way of fusion. Tin combines with copper, at a temperature much lower than is necessary to fuse the copper alone. On this is grounded the method of tinning copper vessels. For this purpose, they are first scraped or scoured; after which they are rubbed with sal ammoniac. They are then heated, and sprinkled with powdered resin, which defends the clean surface of the copper from acquiring the slight film of oxide, that would prevent the adhesion of the tin to its surface. The melted tin is then poured in, and spread about. An extremely small quantity adheres to the copper, which may perhaps be supposed insufficient to prevent the noxious effects of the copper, as perfectly as might be wished.

When tin is melted with copper, it composes the compound called bronze. In this metal the specific gravity is always greater than would be deduced by computation from the quantities and specific gravities of its component parts. The uses of this hard, sonorous, and durable composition, in the fabrication of cannon, bells, statues, and other articles, are well known. Bronzes and bell-metals are not usually made of copper and tin only, but have other admixtures, consisting of lead, zinc, or arsenic, according to the motives of profit, or other inducements of the artist. But the attention of the philosopher is more particularly directed to the mixture of copper and tin, on account of its being the substance of which the speculums of reflecting telescopes are made. See SPECULUM. The ancients made cutting instruments of this alloy. A dagger analyzed by Mr. Hielm consisted of 83⅞ copper, and 16⅛ tin.

Copper unites with bismuth, and forms a reddish-white alloy. With arsenic it forms a white brittle compound, called tombac. With zinc it forms the compound called brass, and distinguished by various other names, according to the proportions of the two ingredients. It is not easy to unite these two metals in considerable proportions by fusion, because the zinc is burnt or volatilized at a heat inferior to that which is required to melt copper; but they unite very well in the way of cementation. In the brass works, copper is granulated by pouring it through a plate of iron, perforated with small holes and luted with clay, into a quantity of water about four feet deep, and continually renewed: to prevent the dangerous explosions of this metal, it is necessary to pour but a small quantity at a time. There are various methods of combining this granulated copper, or other small pieces of copper, with the vapour of zinc. Calamine, which is an ore of zinc, is pounded, calcined, and mixed with the divided copper, together with a portion of charcoal. These being exposed to the heat of a wind furnace, the zinc becomes revived, rises in vapour, and combines with the copper, which it converts into brass. The heat must be continued for a greater or less number of hours, according to the thickness of the pieces of copper, and other circumstances; and at the end of the process, the heat being suddenly raised, causes the brass to melt, and occupy the lower part of the crucible. The most scientific method of making brass seems to be that mentioned by Cramer. The powdered calamine, being mixed with an equal quantity of charcoal and a portion of clay, is to be rammed into a melting vessel, and a quantity of copper, amounting to two-thirds of the weight of calamine, must be placed on the top, and covered with charcoal. By this management the volatile zinc ascends, and converts the copper into brass, which flows into the rammed clay; consequently, if the calamine contain lead, or any other metal, it will not enter into the brass, the zinc alone being raised by the heat.

A fine kind of brass, which is supposed to be made by cementation of copper plates with calamine, is hammered out into leaves in Germany; and is sold very cheap in this country, under the name of Dutch gold, or Dutch metal. It is about five times as thick as gold leaf; that is to say, it is about one sixty-thousandth of an inch thick.

Copper unites readily with antimony, and affords a compound of a beautiful violet colour. It does not readily unite with manganese. With tungsten it forms a dark brown spongy alloy, which is somewhat ductile. Seen ORES OF COPPER.

* Verdigris, and other preparations of copper, act as virulent poisons, when introduced in very small quantities into the stomachs of animals. A few grains are sufficient for this effect. Death is commonly preceded by very decided nervous disor-

ders, such as convulsive movements, tetanus, general insensibility, or a palsy of the lower extremites. This event happens frequently so soon, that it could not be occasioned by inflammation or erosion of the *primæ viæ;* and indeed, where these parts are apparently sound. It is probable that the poison is absorbed, and through the circulation, acts on the brain and nerves. The cupreous preparations are no doubt very acrid, and if death do not follow their immediate impression on the sentient system, they will certainly inflame the intestinal canal. The symptoms produced by a dangerous dose of copper are exactly similar to those which are enumerated under arsenic, only the taste of copper is strongly felt. The only chemical antidote to cupreous solutions whose operation is well understood, is water strongly impregnated with sulphuretted hydrogen. The alkaline hydrosulphurets are acrid, and ought not to be prescribed.

But we possess in sugar, an antidote to this poison of undoubted efficacy, though its mode of action be obscure. M. Duval introduced into the stomach of a dog, by means of a caoutchouc tube, a solution in acetic acid, of four French drachms of oxide of copper. Some minutes afterwards he injected into it four ounces of strong sirup. He repeated this injection every half-hour, and employed altogether 12 ounces of sirup. The animal experienced some tremblings and convulsive movements. But the last injection was followed by a perfect calm. The animal fell asleep, and awakened free from any ailment.

Orfila relates several cases of individuals who had by accident or intention swallowed poisonous doses of acetate of copper, and who recovered by getting large doses of sugar. He uniformly found, that a dose of verdigris which would kill a dog in the course of an hour or two, might be swallowed with impunity, provided it was mixed with a considerable quantity of sugar.

As alcohol has the power of completely neutralizing, in the ethers, the strongest muriatic and hydriodic acids, so it would appear, that sugar can neutralize the oxides of copper and lead. The neutral saccharate of lead, indeed, was employed by Berzelius in his experiments, to determine the prime equivalent of sugar. If we boil for half an hour, in a flask, an ounce of white sugar, an ounce of water, and 10 grains of verdigris, we obtain a green liquid, which is not affected by the nicest tests of copper, such as ferroprussiate of potash, ammonia, and the hydrosulphurets. An insoluble green carbonate of copper remains at the bottom of the flask.*

COPPERAS. Sulphate of iron.

* CORALS seem to consist of carbonate of lime and animal matter, in equal proportions.*

CORK is the bark of a tree of the oak kind, very common in Spain and the other southern parts of Europe.

By the action of the nitric acid it was found to be acidified. See ACID (SUBERIC).

* Cork has been recently analyzed by Chevreul by digestion, first in water and then in alcohol. By distillation there came over an aromatic principle, and a little acetic acid. The watery extract contained a yellow and a red colouring matter, an undetermined acid, gallic acid, an astringent substance, a substance containing azote, a substance soluble in water and insoluble in alcohol, gallate of iron, lime, and traces of magnesia. 20 parts of cork treated in this way, left 17.15 of insoluble matter. The undissolved residue being treated a sufficient number of times with alcohol, *yielded* a variety of bodies, but which seem reducible to three; namely, *cerin*, resin, and an oil. The ligneous portion of the cork still weighed 14 parts, which is called *suber*.*

CORK (FOSSIL). See ASBESTOS.

CORROSIVE SUBLIMATE. See MERCURY.

* CORUNDUM. According to Professor Jameson, this mineral genus contains 3 species, viz. *octohedral* corundum, *rhomboidal* corundum, and *prismatic* corundum.

1. *Octohedral*, is subdivided into 3 subspecies, viz. automalite, ceylanite, and spinel.

2. *Rhomboidal* corundum, contains 4 subspecies, viz. salamstone, sapphire, emery, and corundum, or adamantine spar.

3. *Prismatic*, or chrysoberyl. See the several sub-species, under their titles in the Dictionary.*

* COTTON. This vegetable fibre is soluble in strong alkaline leys. It has a strong affinity for some earths, particularly alumina, several metallic oxides, and tannin. Nitric acid, aided by heat, converts cotton into oxalic acid.*

* COUCH. The heap of moist barley about 16 inches deep on the malt-floor.*

* CREAM. The oily part of milk, which rises to the surface of that liquid, mixed with a little curd and *serum*. When churned, butter is obtained. Heat separates the oily part, but injures its flavour.*

CREAM OF TARTAR. See ACID (TARTARIC).

* CRICHTONITE. A mineral so called in honour of Dr. Crichton, physician to the Emperor of Russia, an eminent mineralogist. It has a velvet-black colour, and crystallizes in very acute small rhomboids. Lustre splendent, inclining to metallic; fracture conchoidal; opaque; scratches fluor spar, but not glass. Infusible before

the blow-pipe. It occurs in primitive rocks along with octahedrite. Professor Jameson thinks it may probably be a new species of titanium-ore.*

Crocus. The yellow or saffron-coloured oxides or iron and copper were formerly called crocus martis and crocus veneris. That of iron is still called crocus simply, by the workers in metal who use it.

* **Cross-stone.** Harmotome, or pyramidal zeolite. Its colour is grayish-white, passing into smoke-gray, sometimes massive, but usually crystallized. Primitive form, a double four-sided pyramid, of 121° 58′ and 86° 36′. Its principal secondary forms are, a broad rectangular four-sided prism, rather acutely acuminated on the extremities with 4 planes, which are set on the lateral edges; the preceding figure, in which the edges formed by the meeting of the acuminating planes, that rest on the broader lateral planes, are truncated; twin crystals of the first form, intersecting each other, in such a manner that a common axis and acumination are formed, and the broader lateral planes make four re-entering angles. The crystals are not large. The surface of the smaller lateral planes is double-plumosely streaked. Lustre glistening, between vitreous and pearly. Of the cleavage, 2 folia are oblique, and 1 parallel to the axis. Fracture perfect conchoidal. Translucent and semi-transparent. Harder than fluor spar, but not so hard as apatite. Easily frangible. Sp. gr. 2.35. It fuses with intumescence and phosphorescence, into a colourless glass. Its constituents are 49 silica, 16 alumina, 18 barytes, and 15 water, by Klaproth. It has hitherto been found only in mineral veins and agate-balls. It occurs at Andreasberg in the Hartz, at Kongsberg in Norway, at Oberstein, Strontian in Argyllshire, and also near Old Kilpatrick in Scotland. *Jameson.**

* **Croton Eleutheria.** Cascarilla bark. The following is Trommsdorf's analysis of this substance, characterized by its emitting the smell of musk when burned. Mucilage and bitter principle 864 parts, resin 688, volatile matter 72, water 48, woody fibres 3024; in 4696 parts.*

* **Crusts**, the bony coverings of crabs, lobsters, &c. Mr. Hatchett found them to be composed of a cartilaginous substance, like coagulated albumen, carbonate of lime, and phosphate of lime. The great excess of the second, above the third ingredient, distinguishes them from bones; while the quantity of the third, distinguishes them from shells. Egg-shells and snail-shells belong to crusts in composition; but the animal matter is in smaller quantity. By Merat-Guillot, 100 parts of lobster crust, consist of 60 carbonate of lime, 14 phosphate of lime, and 26 cartilaginous matter. 100 of hen's egg-shells, consist of 89.6 carbonate of lime, 5.7 phosphate of lime, 4.7 animal matter.*

* **Cryolite.** A mineral which occurs massive, disseminated, and in thick lamellar concretions. Its colours are white and yellowish-brown. Lustre vitreous, inclining to pearly. Cleavage fourfold, in which the folia are parallel with an equiangular four-sided pyramid. Fracture uneven. Translucent. Harder than gypsum. Easily frangible. Sp. gr. 2.95. It becomes more translucent in water. It melts in the heat of a candle. Before the blow-pipe, it becomes first very liquid, and then assumes a slaggy appearance. It consists, by Klaproth, of 24 alumina, 36 soda, and 40 fluoric acid and water. It is therefore a soda-fluate of alumina. If we regard it as composed of definite proportions, we may have

1 prime	alumina,	3.2	26.33	
1 do.	soda,	3.95	32.51	
2 do.	acid,	2.75	22.63	} 41.16.
2 do.	water,	2.25	18.53	
		12.15	100.00	

Vauquelin's analysis of the same mineral gives 47 acid and water, 32 soda, and 21 alumina. This curious and rare mineral has hitherto been found only in West Greenland, at the arm of the sea named Arksut, 30 leagues from the colony of Juliana Hope. It occurs in gneiss. Mr. Allan of Edinburgh had the merit of recognizing a large quantity of this mineral, in a neglected heap brought into Leith, from a captured Danish vessel. It had been collected in Greenland by that indefatigable mineralogist M. Gieseke.*

* **Cryophorus.** The frost-bearer or carrier of cold, an elegant instrument invented by Dr. Wollaston, to demonstrate the relation between evaporation at low temperatures, and the production of cold. If 32 grains of water, says this profound philosopher, were taken at the temperature of 62°, and if one grain of this were converted into vapour by absorbing 960°, then the whole quantity would lose $\frac{960^\circ}{32} = 30^\circ$, and thus be reduced to the temperature of 32°. If from the 31 grains which still remain in the state of water, four grains more were converted into vapour by absorbing 960°, then the remaining 27 grains must have lost $\frac{4}{27}$ of 960° $= 142^\circ$, which is rather more than sufficient to convert the whole into ice. In an experiment conducted upon a small scale, the proportional quantity evaporated did not differ much from this estimate.

If it be also true that water, in assuming the gaseous state, even at a low temperature, expands to 1800 times its former bulk, then in attempting to freeze the small quantity of water above mentioned, it would be requisite to have a dry vacuum with the capacity of $5\times1800=9000$ grains of water. But let a glass tube be taken, having its internal diameter about one-eighth of an inch, with a ball at each extremity of about one inch diameter, and let the tube be bent to a right angle at the distance of half an inch from each ball. One of these balls should be somewhat less than half full of water, and the remaining cavity should be as perfect a vacuum as can readily be obtained; which is effected by making the water boil briskly in the one ball, before sealing up the capillary opening left in the other. If the empty ball be immersed in a freezing mixture of snow and salt, the water in the other ball, though at the distance of two or three feet, will be frozen solid in the course of a very few minutes. The vapour contained in the empty ball is condensed by the common operation of cold, and the vacuum produced by this condensation gives opportunity for a fresh quantity to arise from the opposite ball, with proportional reduction of its temperature.*

* **CRYSTAL.** When fluid substances are suffered to pass with adequate slowness to the solid state, the attractive forces frequently arrange their ultimate particles, so as to form regular polyhedral figures, or geometrical solids, to which the name of crystals has been given. Most of the solids which compose the mineral crust of the earth, are found in the crystallized state. Thus granite consists of crystals of quartz, feldspar, and mica. Even mountain masses like clay-slate, have a regular tabulated form. Perfect mobility among the corpuscles is essential to crystallization. The chemist produces it either by igneous fusion, or by solution in a liquid. When the temperature is slowly lowered in the former case, or the liquid slowly abstracted by evaporation in the latter, the attractive forces resume the ascendancy, and arrange the particles in symmetrical forms. Mere approximation of the particles, however, is not alone sufficient for crystallization. A hot saturated saline solution, when screened, from all agitation, will contract by cooling into a volume much smaller, than what it occupies in the solid state, without crystallizing. Hence the molecules must not only be brought within a certain limit of each other, for their concreting into crystals; but they must also change the direction of their poles, from the fluid collocation, to their position in the solid state.

This reversion of the poles may be effected, 1st, By contact of any part of the fluid, with a point of a solid, of similar composition previously formed. 2d, Vibratory motions, communicated either from the atmosphere, or any other moving body, by deranging, however slightly, the fluid polar direction, will instantly determine the solid polar arrangement, when the balance had been rendered nearly even, by previous removal of the interstitial fluid. On this principle we explain the regular figures which particles of dust or iron assume, when they are placed on a vibrating plane, in the neighbourhood of electrized or magnetized bodies. 3d, Negative or resinous voltaic electricity instantly determines the crystalline arrangement, while positive voltaic electricity counteracts it. On this subject, I beg to refer the reader to an experimental paper, which I published in the fourth volume of the Journal of Science, p. 106. Light also favours crystallization, as is exemplified with camphor dissolved in spirits, which crystallizes in bright, and re-dissolves in gloomy weather.

It might be imagined, that the same body would always concrete in the same, or at least in a similar crystalline form. This position is true, in general, for the salts crystallized in the laboratory; and on this uniformity of figure, one of the principal criteria between different salts depends. But even these forms are liable to many modifications, from causes apparently slight; and in nature, we find frequently the same chemical substance, crystallized in forms apparently very dissimilar. Thus, carbonate of lime assumes the form of a rhomboid, of a regular hexahedral prism, of a solid terminated by 12 scalene triangles, or of a dodecahedron with pentagonal faces, &c. Bisulphuret of iron or martial pyrites produces sometimes cubes and sometimes regular octohedrons, at one time dodecahedrons with pentagonal faces, at another icosahedrons with triangular faces, &c.

While one and the same substance lends itself to so many transformations, we meet with very different substances, which present absolutely the same form. Thus fluate of lime, muriate of soda, sulphuret of iron, sulphuret of lead, &c. crystallize in cubes, under certain circumstances; and in other cases, the same minerals, as well as sulphate of alumina and the diamond, assume the form of a regular octohedron.

Romé de l'Isle first referred the study of crystallization, to principles conformable to observation. He arranged together, as far as possible, crystals of the same nature. Among the different forms relative to each species, he chose one as the most proper, from its simplicity, to be regarded as the primitive form; and by supposing it truncated in different ways, he deduced the other forms from it, and determined a gradation, a series of transitions between this same form, and that of polyhedrons, which seemed to be still further removed from it. To the descriptions and figures which he gave of the crystalline forms, he added the results of the mechanical measurement of their principal angles, and showed that these angles were constant in each variety.

The illustrious Bergmann, by endeavouring to penetrate to the mechanism of the structure of crystals, considered the different forms relative to one and the same substance, as produced by a superposition of planes, sometimes constant and sometimes variable, and decreasing around one and the same primitive form. He applied this primary idea to a small number of crystalline forms, and verified it with respect to a variety of calcareous spar§ by fractures, which enabled him to ascertain the position of the nucleus, or of the primitive form, and the successive order of the laminæ covering this nucleus. Bergmann, however, stopped here, and did not trouble himself either with determining the laws of structure, or applying calculation to it. It was a simple sketch, of the most prominent point of view in mineralogy, but in which we see the hand of the same master who so successfully filled up the outlines of chemistry.

In the researches which M. Haüy undertook, about the same period, on the structure of crystals, he proposed combining the form and dimensions of integrant molecules with simple and regular laws of arrangement, and submitting these laws to calculation. This work produced a mathematical theory, which he reduced to analytical formulæ, representing every possible case, and the application of which to known forms leads to valuations of angles, constantly agreeing with observation.

Theory of the structure of Crystals.

Primitive forms.—The idea of referring to one of the same primitive forms, all the forms which may be assumed by a mineral substance, of which the rest may be regarded as being modifications only, has frequently suggested itself to various philosophers, who have made crystallography their study.

The mechanical division of minerals, which is the only method of ascertaining their true primitive form, proves that this form is invariable while we operate upon the same substance, however diversified or dissimilar the forms of the crystals belonging to this substance may be. Two or three examples will serve to place this truth in its proper light.

Take a regular hexahedral prism of carbonate of lime (Pl. XIII. figs. 1 and 2). If we try to divide it parallel to the edges. from the contours of the bases, we shall find, that three of these edges taken alternately in the upper part, for instance, the edges *l f*, *c d*, *b m*, may be referred to this division: and in order to succeed in the same way with respect to the inferior base, we must chuse, not the edges *l′ f′*, *c′ d*,′ *b′ m′*, which correspond with the preceding, but the intermediate edges *d′ f′*, *b′ c′*, *l′ m′*.

The six sections will uncover an equal number of trapeziums. Three of the latter are represented upon fig. 2. viz. the two which intercept the edges *l f*, *c d*, and are designated by *p p o o*, *a a k k*, and that which intercepts the lower edge *d′ f′*, and which is marked by the letters *n n i i*.

Each of these trapeziums will have a lustre and polish, from which we may easily ascertain, that it coincides with one of the natural joints of which the prism is the assemblage. We shall attempt in vain to divide the prism in any other direction. But if we continue the division parallel to the first sections, it will happen that on one hand the surfaces of the bases will always become narrower, while on the other hand, the altitudes of the lateral planes will decrease; and at the term at which the bases have disappeared, the prism will be changed into a dodecahedron (fig. 3.), with pentagonal faces, six of which, such as *o o i* O *e*, *o* I *k i i*, &c. will be the residues of the planes of the prism; and the six others E A I *o o*, O A′ K *i i*, &c. will be the immediate result of the mechanical division.

Beyond this same term, the extreme faces will preserve their figure and dimensions, while the lateral faces will incessantly diminish in height, until the points *o*, *k*, of the pentagon *o* I *k i i*, coming to be confounded with the points *i*, *i*, and so on with the other points similarly situated, each pentagon will be reduced to a simple triangle, as we see in fig. 4.§

Lastly, when new sections have obliterated these triangles, so that no vestige of the surface of the prism remains (fig. 1.), we shall have the nucleus or the primitive form, which will be an obtuse rhomboid (fig. 5.), the grand angle of which E A I or E O I, is 101° 32′ 13″.‡

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§ This is what has been called *dent de cochon*, but which M. Haüy calls *metastatic*.

§ The points which are confounded, two and two, upon this figure, are each marked with the two letters which served to designate them when they were separated, as in fig. 3.

‡ It is observed, that each trapezium, such as *p p o o* (fig. 2.) uncovered by the first sections, is very sensibly inclined from the same quantity, as well upon the residue *p p d e b m* of the base, as upon the residue *o o f′ l′* of the adjacent plane. Setting out from this equality of inclinations, we deduce from it, by calculation, the va-

If we try to divide a crystal of another species, we shall have a different nucleus. For instance, a cube of fluate of lime will give a regular octohedron, which we succeed in extracting by dividing the cube upon its eight solid angles, which will in the first place discover eight equilateral triangles, and we may pursue the division, always parallel to the first sections, until nothing more remains of the faces of the cube. The nucleus of the crystals of sulphate of barytes will be a straight prism with rhombous bases; that of the crystals of phosphate of lime, a regular hexahedral prism; that of sulphuretted lead, a cube, &c.; and each of these forms will be constant relative to the entire species, in such a manner, that its angles will not undergo any appreciable variation.

Having adopted the word *primitive form* in order to designate the nucleus of crystals, M. Haüy calls *secondary forms*, such varieties as differ from the primitive form.

In certain species, crystallization also produces this last form immediately.

We may define the primitive form, a solid of a constant form, engaged symmetrically in all the crystals of one and the same species, and the faces of which follow the directions of the laminæ which form these crystals.

The primitive forms hitherto observed, are reduced to six, viz. the parallelopipedon, the octohedron, the tetrahedron, the regular hexahedral prism, the dodecahedron with rhombous planes, all equal and similar, and the dodecahedron with triangular planes, composed of two straight pyramids joined base to base.

Forms of integrant Molecules.—The nucleus of a crystal is not the last term of of its mechanical division. It may always be subdivided parallel to its different faces, and sometimes in other directions also. The whole of the surrounding substance is capable of being divided by strokes parallel to those which take place with respect to the primitive form.

If the nucleus be a parallelopipedon, which cannot be subdivided except by blows parallel to its faces, like that which takes place with respect to carbonated lime, it is evident that the integrant molecule will be similar to this nucleus itself.

But it may happen that the parallelopipedon admits of further sections in other directions than the former.

We may reduce the forms of the integrant molecules of all crystals to three, which are, the tetrahedron, or the simplest of the pyramids; the triangular prism, or the simplest of all the prisms; and the parallelopipedon, or the simplest among the solids, which have their faces parallel two and two. And since four planes at least are necessary for circumscribing a space, it is evident that the three forms in question, in which the number of faces is successively four, five, and six, have still, in this respect, the greatest possible simplicity.

Laws to which the Structure is subjected.—After having determined the primitive forms, and those of the integrant molecules, it remains to inquire into the laws pursued by these molecules in their arrangement, in order to produce these regular kinds of envelopes, which disguise one and the same primitive form in so many different ways.

Now, observation shows, that this surrounding matter is an assemblage of laminæ, which, setting out from the primitive form, decrease in extent, both on all sides at once, and sometimes in certain particular parts only. This decrement is effected by regular subtractions of one or more rows of integrant molecules; and the theory, in determining the number of these rows by means of calculation, succeeds in representing all the known results of crystallization, and even anticipates future discoveries, indicating forms which, being still hypothetical only, may one day be presented to the inquiries of the philosopher.

Decrements on the Edges.—Let $s\ s'$ (fig. 6. Pl. XIII.) be a dodecahedron with rhombic planes. This solid, which is one of the six primitive forms of crystals, also presents itself occasionally as a secondary form, and in this case it has as a nucleus, sometimes a cube, and sometimes an octohedron. Supposing the nucleus to be a cube:—

In order to extract this nucleus, it is sufficient successively to remove the six solid angles composed of four planes, such as s, r, t, &c. by sections adapted to the direction of the small diagonals. These sections will display as many squares $A\ E\ O\ I$, $E\ O\ O'\ E'$, $I\ O\ O'\ I'$ (fig. 7.), &c. which will be the faces of the cube.

Let us conceive that each of these faces is subjected to a series of decreasing laminæ solely composed of cubic molecules, and that every one of these laminæ exceeds the succeeding one, towards its four edges, by a quantity equal to one course of these same molecules. Afterwards we shall designate the decreasing laminæ which envelope the mucleus, by the name of *laminæ of superposition*. Now, it is easy to conceive that the different series will produce six quadrangular pyramids, similar in some respects to the quadrangular steps of a column, which will rest on the faces of the cube. Three of these pyramids are represented in fig. 8. and have their summits in s, t, r'.

Now, as there are six quadrangular py-

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lue of the angles with the precision of minutes and seconds, which mechanical measurements are not capable of attaining.

ramids, we shall therefore have twenty-four triangles; such as O *s* I, O *t* I, &c. But because the decrement is uniform from *s* to *t*, and so on with the rest; the triangles taken two and two are on a level, and form a rhomb *s* O *t* I. The surface of the solid will therefore be composed of twelve equal and similar rhombs; *i. e.* this solid will have the same form with that which is the subject of the problem. This structure takes place, although imperfectly, with respect to the crystals called *boracic spars*.

The dodecahedron now under consideration, is represented by fig. 8. in such a way that the progress of the decrement may be perceived by the eye. On examining the figure attentively, we shall find that it has been traced on the supposition, that the cubic nucleus has on each of its edges 17 ridges of molecules; whence it follows, that each of its faces is composed of 289 facets of molecules, and that the whole solid is equal to 4913 molecules. On this hypothesis, there are eight laminæ of superposition, the last of which is reduced to a simple cube, whose edges determine the numbers of molecules which form the series 15, 13, 11, 9, 7, 5, 3, 1, the difference being 2, because there is one course subtracted from each extremity.

Now, if instead of this coarse kind of masonry, which has the advantage of speaking to the eye, we substitute in our imagination the infinitely delicate architecture of nature, we must conceive the nucleus as being composed of an incomparably greater number of imperceptible cubes. In this case, the number of laminæ of superposition will also be beyond comparison greater than on the preceding hypothesis. By a necessary consequence, the furrows which form these laminæ by the alternate projecting and re-entering of their edges, will not be cognizable by our senses; and this is what takes place in the polyhedra which crystallization has produced at leisure, without being disturbed in its progress.

M. Haüy calls *decrements in breadth*, those in which each lamina has only the height of a molecule, so that their whole effect, by one, two, three, &c. courses, is in the way of breadth. *Decrements in height* are those in which each lamina, exceeding only the following one by a single course in the direction of the breadth, may have a height double, triple, quadruple, &c. to that of a molecule: this is expressed by saying that the decrement takes place by two courses, three courses, &c. in height.

We are indebted to Dr. Wollaston for ideas on the *ultimate* cause of crystalline forms, equally ingenious and profound. They were communicated to the Royal Society, and published in their transactions for the year 1813.

Among the known forms of crystallized bodies, there is no one common to a greater number of substances than the regular octohedron, and no one in which a corresponding difficulty has occurred with regard to determining which modification of its form is to be considered as primitive; since in all these substances the tetrahedron appears to have equal claim to be received as the original from which all their other modifications are to be derived.

The relation of these solids to each other is most distinctly exhibited to those who are not much conversant with crystallography, by assuming the tetrahedron as primitive, for this may immediately be converted into an octohedron by the removal of four smaller tetrahedrons from its solid angles. (Plate XIV. fig. 1.)

The substance which most readily admits of division by fracture into these forms, is fluor spar; and there is no difficulty in obtaining a sufficient quantity for such experiments. But it is not, in fact, either the tetrahedron or the octohedron, which first presents itself as the apparent primitive form obtained by fracture.

If we form a plate of uniform thickness by two successive divisions of the spar, parallel to each other, we shall find the plate divisible into prismatic rods, the section of which is a rhomb of 70° 32′ and 109° 28′ nearly; and if we again split these rods transversely, we shall obtain a number of regular acute rhomboids, all similar to each other, having their superficial angles 60° and 120° and presenting an appearance of primitive molecule, from which all the other modifications of such crystals might very simply be derived. And we find, moreover, that the whole mass of fluor might be divided into, and conceived to consist of, these acute rhomboids alone, which may be put together so as to fit each other without any intervening vacuity.

But, since the solid thus obtained (as represented fig. 2.) may be again split by natural fractures at right angles to its axis (fig. 3.), so that a regular tetrahedron may be detached from each extremity, while the remaining portion assumes the form of a regular octohedron; and since every rhomboid that can be obtained, must admit of the same division into one octohedron and two tetrahedrons, the rhomboid can no longer be regarded as the primitive form; and since the parts into which it is divisible are dissimilar, we are left in doubt which of them is to have precedence as primitive.

In the examination of this question, whether we adopt the octohedron or the tetrahedron as the primitive form, since neither of them can fill space without leaving vacuities, there is a difficulty in conceiving any arrangement in which the particles will remain at rest: for, whether we suppose, with the Abbé Haüy, that the particles are tetrahedral with octohedral cavities, or, on the contrary, octohedral particles regularly arranged with tetrahedral cavities, in each case the mutual contact of adjacent particles is only at their edges; and, although in such an arrangement it must be admitted that there may be an equilibrium, it is evidently unstable, and ill adapted to form the basis of any permanent crystal.

With respect to fluor spar and such other substances as assume the octohedral and tetrahedral forms, all difficulty is removed, says Dr. Wollaston, by supposing the elementary particles to be perfect spheres, which, by mutual attraction, have assumed that arrangement which brings them as near to each other as possible.

The relative position of any number of equal balls in the same plane, when gently pressed together, forming equilateral triangles with each other (as represented perspectively in fig. 4.), is familiar to every one; and it is evident that, if balls so placed were cemented together, and the stratum thus formed were afterwards broken, the straight lines in which they would be disposed to separate would form angles of 60° with each other.

If a single ball were placed any where at rest upon the preceding stratum, it is evident that it would be in contact with three of the lower balls (as in fig. 5.), and that the lines joining the centres of four balls so in contact, or the planes touching their surfaces, would include a regular tetrahedron, having all its equilateral triangles.

The construction of an octohedron, by means of spheres alone, is as simple as that of the tetrahedron. For, if four balls be placed in contact on the same plane, in form of a square, then a single ball resting upon them in the centre, being in contact with each pair of balls, will present a triangular face rising from each side of the square, and the whole together will represent the superior apex of an octohedron; so that a sixth ball similarly placed underneath the square will complete the octohedral group, fig. 6.

There is one observation with regard to these forms that will appear paradoxical, namely that a structure, which, in this case, was begun upon a square foundation, is really intrinsically the same as that which is begun upon the triangular basis. But if we lay the octohedral group, which consists of six balls, on one of its triangular sides, and, consequently, with an opposite triangular face uppermost, the two groups, consisting of three balls each, are then situated precisely as they would be found in two adjacent strata of the triangular arrangement. Hence, in this position, we may readily convert the octohedron into a regular tetrahedron, by addition of four more balls (fig. 7.). One placed on the top of the three that are uppermost forms the apex; and if the triangular base, on which it rests, be enlarged by addition of three more balls, regularly disposed around it, the entire group of ten balls will then be found to represent a regular tetrahedron.

For the purpose of representing the acute rhomboid, two balls must be applied at opposite sides of the smallest octohedral group, as in fig. 9. And if a greater number of balls be placed together, fig. 10. and 11. in the same form, then a complete tetrahedral group may be removed from each extremity, leaving a central octohedron, as may be seen in fig. 11. which corresponds to fig. 3.

We have seen, that by due application of spheres to each other, all the most simple forms of one species of crystal will be produced, and it is needless to pursue any other modifications of the same form, which must result from a series of decrements produced according to known laws.

Since then the simplest arrangement of the most simple solid that can be imagined, affords so complete a solution of one of the most difficult questions in crystallography, we are naturally led to inquire what forms would probably occur from the union of other solids most nearly allied to the sphere. And it will appear that by the supposition of elementary particles that are spheroidical, we may frame conjectures as to the origin of other angular solids well known to crystallographers.

The obtuse Rhomboid.

If we suppose the axis of our elementary speroid to be its shortest dimension, a class of solids will be formed which are numerous in crystallography. It has been remarked above, that by the natural grouping of spherical particles, fig. 10. one resulting solid is an acute rhomboid, similar to that of fig. 2. having certain determinate angles, and its greatest dimension in the direction of its axis. Now, if other particles having the same relative arrangement be supposed to have the form of oblate spheroids, the resulting solid, fig. 12. will still be a regular rhomboid; but the measures of its angles will be different from those of the former, and will be more or less obtuse according to the degree of oblateness of the primitive spheroid.

It is at least possible that carbonate of lime and other substances, of which the forms are derived from regular rhomboids as their primitive form, may, in fact, consist of oblate spheroids as elementary particles.

Hexagonal Prisms.

If our elementary spheroid be on the

contrary oblong, instead of oblate, it is evident that, by mutual attraction, their centres will approach nearest to each other when their axes are parallel, and their shortest diameters in the same plane (fig. 13.). The manifest consequence of this structure would be, that a solid so formed would be liable to split into plates at right angles to the axes, and the plates would divide into prisms of three or six sides with all their angles equal, as occurs in phosphate of lime, beryl, &c.

It may farther be observed, that the proportion of the height to the base of such a prism, must depend on the ratio between the axes of the elementary spheroid.

The Cube.

Let a mass of matter be supposed to consist of spherical particles all of the same size, but of two different kinds in equal numbers, represented by black and white balls; and let it be required that, in their perfect intermixture, every black ball shall be equally distant from all surrounding white balls, and that all adjacent balls of the same denomination shall also be equidistant from each other. The Doctor shows, that these conditions will be fulfilled, if the arrangement be cubical, and that the particles will be *in equilibrio*. Fig. 14. represents a cube so constituted of balls, alternately black and white throughout. The four black balls are in view. The distances of their centres being every way a superficial diagonal of the cube, they are equidistant, and their configuration represents a regular tetrahedron; and the same is the relative situation of the four white balls. The distances of dissimilar adjacent balls are likewise evidently equal; so that the conditions of their union are complete, as far as appears in the small group: and this is a correct representative of the entire mass, that would be composed of equal and similar cubes.

There remains one observation with regard to the spherical form of elementary particles, whether actual or virtual, that must be regarded as favourable to the foregoing hypothesis, namely, that many of those substances, which we have most reason to think simple bodies, as among the class of metals, exhibit this further evidence of their simple nature, that they crystallize in the octohedral form, as they would do if their particles were spherical.

But it must, on the contrary, be acknowledged, that we can at present assign no reason why the same appearance of simplicity should take place in fluor spar, which is presumed to contain at least two elements; and it is evident that any attempts to trace a general correspondence between the crystallographical and supposed chemical elements of bodies, must in the present state of these sciences, be premature.

Any sphere when not compressed will be surrounded by twelve others, and, consequently, by a slight degree of compression, will be converted into a dodecahedron, according to the most probable hypothesis of simple compression.

The instrument for measuring the angles of crystals is called a goniometer, of which there are two kinds. 1. The goniometer of M. Carangeau, used by M. Haüy, consists of two parallel blades, jointed like those of scissars, and capable of being applied to a graduated semicircular sector, which gives the angle to which the joint is opened, in consequence of the previous apposition of the two blades to the angle of the crystal. 2. The reflective goniometer of Dr. Wollaston, an admirable invention, which measures the angles of the minutest possible crystals with the utmost precision. An account of this beautiful instrument may be found in the Phil. Trans. for 1809, and in Tilloch's Magazine for February 1810, vol. 35. Mr. William Phillips published, in the 2d volume of the Geological Transactions, an elaborate series of measurements with this goniometer. A striking example of the power of this instrument in detecting the minutest forms with precision was afforded, by its application to a crystalline jet-black sand, which Dr. Clarke got from the island Jean Mayen, in the Greenland seas. "Having therefore," says Dr. Clarke, "selected a crystal of this form, but so exceedingly minute as scarcely to be discernible to the naked eye, I fixed it upon the moveable plane of Dr. Wollaston's reflecting goniometer. A double image was reflected by one of the planes of the crystal, but the image reflected by the contiguous plane was clear and perfectly perceptible, by which I was enabled to measure the angle of inclination; and after repeating the observation several times, I found it equal to 92° or 92½°. Hence it is evident that these crystals are not zircons, although they possess a degree of lustre quite equal to that of zircon. In this uncertainty, I sent a small portion of the sand to Dr. Wollaston, and requested that he would himself measure the *angle* of the particles exhibiting splendant surfaces. Dr. Wollaston pronounced the substance to be pyroxene; having an angle, according to his observation, of 92½°. He also informed me that the sand was similar to that of Bolsenna in Italy." Such a ready means of minute research forms a delightful aid to the chemical philosopher, as well as the mineralogist. M. Haüy, by a too rigid adherence to the principle of geometrical simplicity, obtained an erroneous determination of the angles in the primary form of carbonate of lime, amounting to 36 minutes of a degree. And by assigning to the magnesian and ferriferous carbonates of lime the same angle as to the simple carbonate, the error became still greater, as will appear from the following comparative measurements.

	Observed angle by Dr. Wollaston's goniometer.	*Theoretic angle.*	*Error.*
Carbonate of lime,	105° 5′	104° 28′ 40″	0° 36′ 20″
Magnesian carbonate,	106° 15′	104° 28′ 40″	1° 46′ 20″
Ferriferous carbonate,	107° 0′	104° 28′ 40″	2° 31′ 20″

M. Haüy will no doubt accommodate his results to these indications of Dr. Wollaston's goniometer, and give his theory all the perfection which its scientific value and elegance deserve.

M. Beudant has lately made many experiments to discover, why a saline principle of a certain kind sometimes impresses its crystalline form upon a mixture, in which it does not, by any means, form the greatest part; and also with the view of determining, why one saline substance may have such an astonishing number of secondary forms, as we sometimes meet with.

The presence of urea makes common salt take an octohedral form although in pure water it crystallizes in cubes, similar to its primitive molecules. Sal ammoniac, which crystallizes in pure water in octohedrons, by means of urea crystallizes in cubes. A very slight excess or deficiency of base in alum, causes it to assume either cubical or octohedral secondary forms; and these forms are so truly secondary, that an octohedral crystal of alum, immerged in a solution which is richer in respect to its basis, becomes enveloped with crystalline layers, which give it at length the form of a cube.

The crystalline form in muddy solutions acquires greater simplicity, losing all those additional *facets* which would otherwise modify their predominant form.

In a gelatinous deposite, crystals are rarely found in groups, but almost always single, and of a remarkable sharpness and regularity of form, and they do not undergo any variations, but those which may result from the chemical action of the substance forming the deposite. Common salt crystallized in a solution of borax, acquires truncations at the solid angles of its cubes; and alum crystallized in muriatic acid, takes a form which M. Beudant has never been able to obtain in any other manner.

30 or 40 per cent of sulphate of copper may be united to the rhomboidal crystallization of sulphate of iron, but it reduces this sulphate to a pure rhomboid, without any truncation either of the angles or the edges. A small portion of acetate of copper reduces sulphate of iron to the same simple rhomboidal form, notwithstanding that this form is disposed to become complicated with additional surfaces. Sulphate of alumina brings sulphate of iron to a rhomboid, with the lateral angles only truncated, or what M. Haüy calls his *variété unitaire;* and whenever this variety of green vitriol is found in the market, where it is very common, we may be sure, according to M. Beudant, that it contains alumina.

Natural crystals mixed with foreign substances, are in general more simple than others, as is shown in a specimen of axinite or violet schorl of Dauphiné, one extremity of which being mixed with chlorite, is reduced to its primitive form; while the other end, which is pure, is varied by many facets produced by different decrements.

In a mingled solution of two or more salts, of nearly equal solubility, the crystallization of one of them may be sometimes determined, by laying or suspending in the liquid, a crystal of that particular salt.

M. Le Blanc states, that on putting into a tall and narrow cylinder, crystals at different heights, in the midst of their saturated saline solution, the crystals at the bottom increase faster than those at the surface, and that there arrives a period when those at the bottom continue to enlarge, while those at the surface diminish and dissolve.

Those salts which are apt to give up their water of crystallization to the atmosphere, and of course become efflorescent, may be preserved by immersion in oil, and subsequent wiping of their surface.

In the Wernerian language of crystallization, the following terms are employed: When a secondary form differs from the cube, the octohedron, &c. only in having several of its angles or edges replaced by a face, this change of the geometrical form is called a *truncation.* The alteration in the principal form produced by two new faces inclined to one another, and which replace by a kind of bevel, an angle, or an edge, is called a *bevelment.* When these new faces are to the number of three or more, they produce what Werner termed a *pointing*, or *acumination*. When two faces unite by an edge in the manner of a roof, they have been called *culmination*. *Replacement* is occasionally used for *bevelment*.

The reader will find some curious observations on crystallization, by Mr. J. F. Daniell, in the 1st volume of the Journal of Science.

Professor Mohs, successor to Werner in Freyberg, Dr. Weiss, professor of mineralogy, in Berlin, and M. Brochant, professor of mineralogy in Paris, have each recently published systems of mineralogy. Pretty copious details, relative to the first, are given in the 3d volume of the Edinburgh Philosophical Journal.*

In a paper in the Journal de Physique, M. Le Blanc gives instructions for obtaining crystals of large size. His method is to employ flat glass or china vessels: to pour into these the solutions boiled down to the point of crystallization: to select the neatest of the small crystals formed, and put them into vessels with more of the mother-water of a solution that has been brought to crystallize confusedly: to turn the crystals at least once a day; and to supply them from time to time with fresh mother-water. If the crystals be laid on their sides they will increase most in length; if on their ends, most in breadth. When they have ceased to grow larger, they must be taken out of the liquor, or they will soon begin to diminish. It may be observed in general, that very large crystals are less transparent than those that are small.

The crystals of metals may be obtained by fusing them in a crucible with a hole in its bottom, closed by a stopper, which is to be drawn out after the vessel has been removed from the fire, and the surface of the metal has begun to congeal. The same effect may be observed if the metal be poured into a plate or dish, a little inclined, which is to be suddenly inclined in the opposite direction, as soon as the metal begins to congeal round its edges. In the first method, the fluid part of the metal runs out of the hole, leaving a kind of cup lined with crystals: in the latter way, the superior part, which is fluid, runs off, and leaves a plate of metal studded over with crystals.

The operation of crystallizing, or crystallization, is of great utility in the purifying of various saline substances. Most salts are suspended in water in greater quantities at more elevated temperatures, and separate more or less by cooling. In this property, and likewise in the quantity of salt capable of being suspended in a given quantity of water, they differ greatly from each other. It is therefore practicable in general to separate salts by due management of the temperature and evaporation. For example, if a solution of nitre and common salt be evaporated over the fire, and a small quantity be now and then taken out for trial, it will be found, at a certain period of the concentration, that a considerable portion of salt will separate by cooling, and that this salt is for the most part pure nitre. When this is seen, the whole fluid may be cooled to separate part of the nitre, after which, evaporation may be proceeded upon as before. This manipulation depends upon the different properties of the two salts with regard to their solubility and crystallization in like circumstances. For nitre is considerably more soluble in hot than in cold water, while common salt is scarcely more soluble in the one case than in the other. The common salt consequently separates in crystals as the evaporation of the heated fluid goes on, and is taken out with a ladle from time to time, whereas the nitre is separated by successive coolings at proper periods.

* **Cube Ore.** Hexahedral Olivenite. Wurfelerz. Wern. This mineral has a pistacio-green colour, of various shades. It occurs massive, and crystallized in the perfect cube; in a cube with four diagonally opposite angles truncated; or in one truncated on all its angles; or finally, both on its edges and angles.

The crystals are small, with planes smooth and splendent. Lustre glistening. Cleavage parallel with the truncations of the angles. Translucent. Streak straw-yellow. Harder than gypsum. Easily frangible. Sp. gr. 3.0. Fuses with disengagement of arsenical vapours. Its constituents are, 31 arsenic acid, 45.5 oxide of iron, 9 oxide of copper, 4 silica, and 10.5 water, by Chenevix. Vauquelin's analysis gives no copper nor silica, but 48 iron, 18 arsenic acid, 2 to 3 carbonate of lime, and 32 water. It is found in veins, accompanied with iron-shot quartz, in Tincroft and various other mines of Cornwall, and at St. Leonard in the Haut-Vienne in France. As an arseniate of iron, it might be ranked among the ores of either this metal or arsenic.—*Jameson.**

Cupel. A shallow earthen vessel, somewhat resembling a cup, from which it derives its name. It is made of phosphate of lime, or the residue of burned bones rammed into a mould, which gives it its figure. This vessel is used in assays wherein the precious metals are fused with lead, which becomes converted into glass, and carries the impure alloy with it. See Assay.

Cupellation. The refining of gold by scorification with lead upon the cupel, is called cupellation. See Assay.

Curd. The coagulum which separates from milk upon the addition of acid, or other substances. See Milk.

***Cyanite**, *or* **Kyanite.** Disthene of Haüy. Its principal colour is Berlin-blue, which passes into gray and green. It occurs massive and disseminated, also in distinct concretions. The primitive form of its crystals is an oblique four-sided prism; and the secondary forms are, an oblique four-sided prism, truncated on the lateral edges, and a twin crystal. The planes are streaked, splendent, and pearly. Cleavage threefold. Translucent or transparent. Surface of the broader lateral planes as hard as apatite; that of the angles, as quartz. Easily frangible. Sp. gr. 3.5. When pure it is idio-electric. Some crystals by friction acquire negative, others positive electricity; hence Haüy's name. It is infusible before the blow-pipe. It consists, by Klaproth, of 43 silica, 55.5 alumina, 0.50 iron, and a trace of potash. It occurs in the granite and mica slate of primitive mountains. It is found near Banchory in Aberdeenshire, and Bocharm in Banffshire; at Airolo on St Gothard, and in various countries of Europe, as well as in Asia and America. It is cut and polished in India as an inferior sort of sapphire.—*Jameson.**

* **Cyanogen.** The compound base of prussic acid. See **Prussine.***

* **Cymophane** of Haüy. The **Chrysoberyl.***

D

Damps. The permanently elastic fluids which are extricated in mines, and re destructive to animal life, are called damps by the miners. The chief distinctions made by the miners, are choak-damp, which extinguishes their candles, hovers about the bottom of the mine, and consists for the most part of carbonic acid gas; and fire-damp, or hydrogen gas, which occupies the superior spaces, and does great mischief by exploding whenever it comes in contact with their lights. See **Gas, Combustion, & Lamp.**

* **Daourite.** A variety of red schorl from Siberia.*

* **Daphnin.** The bitter principle of *Daphne Alpina*, discovered by M. Vauquelin. From the alcoholic infusion of this bark, the resin was separated by its concentration. On diluting the tincture with water, filtering, and adding acetate of lead, a yellow *daphnate* of lead fell, from which sulphuretted hydrogen separated the lead, and left the daphnin in small transparent crystals. They are hard, of a grayish colour, a bitter taste when heated, evaporate in acrid acid vapours, sparingly soluble in cold, but moderately in boiling water. It is stated, that its solution is not precipitated by acetate of lead; yet acetate of lead is employed in the first process to throw it down.*

***Datolite.** Datholit of Werner. This species is divided into two sub-species, viz. Common Datolite, and Botrioidal Datolite.

1. Common Datolite. Colour white of various shades, and greenish-gray, inclining to celadine-green. It occurs in large coarse, and small granular distinct concretions, and crystallized. Primitive form, an oblique four-sided prism of 109° 28′ and 70° 32′. The principal secondary forms, are the low oblique four-sided prism, and the rectangular four-sided prism, flatly acuminated on the extremities, with four planes which are set on the lateral planes. The crystals are small and in druses. Lustre shining and resinous. Cleavage imperfect, parallel with the lateral planes of the prism. Fracture fine grained, uneven, or imperfect conchoidal. Translucent or transparent. Fully as hard as apatite. Very brittle, and difficultly frangible. Sp. gr. 2.9. When exposed to the flame of a candle it becomes opaque, and may then be rubbed down between the fingers. Before the blow-pipe it intumesces into a milk-white coloured mass, and then melts into a globule of a pale rose colour. Its constituents are, by Klaproth, silica 36.5, lime 35.5, boracic acid 24.0, water 4, trace of iron and manganese. It is associated with large foliated granular calcareous spar, at the mine of Nodebroe, near Arendal in Norway. It resembles prehnite, but is distinguished by its resinous lustre, compact fracture, inferior hardness, and not becoming electric by heating.—*Jameson.**

* 2. **Botrioidal Datolite.** See **Botryolite.***

* **Datura.** A vegeto-alkali obtained from **Datura Stramonium.***

* **Dead-Sea Water.** See **Water.***

Decantation. The action of pouring off the clearer part of a fluid by gently inclining the vessel after the grosser parts have been suffered to subside.

Decoction. The operation of boiling. This term is likewise used to denote the fluid itself which has been made to take up certain soluble principles by boiling. Thus we say a decoction of the bark, or other parts of vegetables, of flesh, &c.

Decomposition is now understood to imply the separation of the component parts or principles of bodies from each other.

The decomposition of bodies forms a very large part of chemical science. It seems probable from the operations we are acquainted with, that it seldom takes place but in consequence of some combination or composition having been effected. It would be difficult to point out an instance of the separation of any of the principles of bodies which has been effected, unless in consequence of some new combination. The only exceptions seem to consist in those separations which are made by heat, and voltaic electricity. See ANALYSIS, GAS, METALS, ORES, SALTS, MINERAL WATERS.

* DECREPITATION. The crackling noise which several salts make when suddenly heated, accompanied by a violent exfoliation of their particles. This phenomenon has been ascribed by Dr. Thomson, and other chemical compilers, to the "sudden conversion of the water which they contain into steam." But the very example, sulphate of barytes, to which these words are applied, is the strongest evidence of the falseness of the explanation; for absolutely dry sulphate of barytes decrepitates furiously, without any possible formation of steam, or any loss of weight. The same thing holds with regard to common salt, calcareous spars, and sulphate of potash, which contain *no water*. In fact, it is the salts which are anhydrous, or destitute of water, which decrepitate most powerfully; those that contain water, generally enter into tranquil liquefaction on being heated. Salts decrepitate, for the same reason that glass, quartz, and cast-iron crack, with an explosive force, when very suddenly heated; namely, from the unequal expansion of the laminæ which compose them, in consequence of their being imperfect conductors of heat. The true cleavage of minerals may often be detected in this way, for they fly asunder at their natural fissures.*

† DEFLAGRATION. This word is used by electricians and chemists, to denote that kind of combustion, which takes place in metallic wires, or leaves, when subjected to galvanic or electric discharges. See GALVANIC DEFLAGRATOR.†

* DELPHINITE. See PISTACITE.*

* DELPHINIA. A new vegetable alkali, recently discovered by MM. Lasseigne and Feneulle, in the *Delphinium staphysagria*, or Stavesacre. It is thus obtained:

The seeds, deprived of their husks, and ground, are to be boiled in a small quantity of distilled water, and then pressed in a cloth. The decoction is to be filtered, and boiled for a few minutes with pure magnesia. It must then be re-filtered, and the residuum left on the filter is to be well washed, and then boiled with highly rectified alcohol, which dissolves out the alkali. By evaporation, a white pulverulent substance, presenting a few crystalline points, is obtained.

It may also be procured by the action of dilute sulphuric acid, on the bruised but unshelled seeds. The solution of sulphate thus formed, is precipitated by subcarbonate of potash. Alcohol separates from this precipitate the vegetable alkali in an impure state.

Pure delphinia obtained by the first process, is crystalline while wet, but becomes opaque on exposure to air. Its taste is bitter and acrid. When heated it melts; and on cooling becomes hard and brittle like resin. If more highly heated, it blackens and is decomposed. Water dissolves a very small portion of it. Alcohol and ether dissolve it very readily. The alcoholic solution renders sirup of violets green, and restores the blue tint of litmus reddened by an acid. It forms soluble neutral salts with acids. Alkalis precipitate the delphinia in a white gelatinous state, like alumina.

Sulphate of delphinia evaporates in the air, does not crystallize, but becomes a transparent mass like gum. It dissolves in alcohol and water, and its solution has a bitter acrid taste. In the voltaic circuit it is decomposed, giving up its alkali at the negative pole.

Nitrate of delphinia, when evaporated to dryness, is a yellow crystalline mass. If treated with excess of nitric acid, it becomes converted into a yellow matter, little soluble in water, but soluble in boiling alcohol. This solution is bitter, is not precipitated by potash, ammonia, or lime-water, and appears to contain no nitric acid, though itself is not alkaline. It is not destroyed by further quantities of acid, nor does it form oxalic acid. Strychnia and morphia take a red colour from nitric acid, but delphinia never does. The muriate is very soluble in water.

The acetate of delphinia does not crystallize, but forms a hard transparent mass, bitter and acrid, and readily decomposed by cold sulphuric acid. The oxalate forms small white plates, resembling in taste the preceding salts.

Delphinia, calcined with oxide of copper, gave no other gas than carbonic acid. It exists in the seeds of the stavesacre, in combination with malic acid, and associated with the following principles: 1. A brown bitter principle, precipitable by acetate of lead. 2. Volatile oil. 3. Fixed oil. 4. Albumen. 5. Animalized matter. 6. Mucus. 7. Saccharine mucus. 8. Yellow bitter principle, not precipitable by acetate of lead. 9. Mineral salts.—*Annales de Chimie et Physique*, vol. xii. p. 358.*

DELIQUESCENCE. The spontaneous assumption of the fluid state by certain saline substances, when left exposed to the air, in consequence of the water they attract from it.

Dephlegmation. Any method by which bodies are deprived of water.

Dephlogisticated. A term of the old chemistry, implying deprived of phlogiston, or the inflammable principle, and nearly synonymous with what is now expressed by *oxygenated*, or *oxidized*.

Dephlogisticated Air. The same with oxygen gas.

Derbyshire Spar. A combination of calcareous earth with a peculiar acid called the **Fluoric**, which see.

* **Desiccation** is most elegantly accomplished, by means of the air-pump and sulphuric acid, as is explained under **Congelation**.*

Destructive Distillation. When organized substances, or their products, are exposed to distillation, until the whole has suffered all that the furnace can effect, the process is called destructive distillation.

Detonation. A sudden combustion and explosion. See **Combustion**, **Fulminating Powders**, and **Gunpowder**.

* **Dew.** The moisture insensibly deposited from the atmosphere on the surface of the earth.

The first facts which could lead to the just explanation of this interesting, and, till very lately, inexplicable natural phenomenon, are due to the late Mr. A. Wilson, professor of astronomy in Glasgow, and his son. The first stated, in the Phil. Trans. for 1771, that on a winter night, during which the atmosphere was several times misty and clear alternately, he observed a thermometer, suspended in the air, always to *rise* from a half to a whole degree, whenever the former state began, and to fall as much as soon as the weather became serene. Dr. Patrick Wilson communicated, in 1786, to the Royal Society of Edinburgh, a valuable paper on hoar-frost, which was published in the first volume of their Transactions. It is replete with new and valuable observations, whose minute accuracy subsequent experience has confirmed. Dr. Wilson had previously, in 1781, described the surface of snow, during a clear and calm night, to be 16° colder than air 2 feet above it; and in the above paper he shows, that the deposition of dew and hoar-frost is uniformly accompanied with the production of cold. He was the first among philosophical observers who noticed this conjunction. But the different force with which different surfaces project or radiate heat being then unknown, Dr. Wilson could not trace the phenomena of dew up to their ultimate source. This important contribution to science has been lately made by Dr. Wells, in his very ingenious and masterly essay on dew.

1. *Phenomena of Dew.*

Aristotle justly remarked, that dew appears only on calm and clear nights. Dr. Wells shows that very little is ever deposited in opposite circumstances; and *that little* only when the clouds are very high. It is never seen on nights both cloudy and windy; and if in the course of the night the weather, from being serene, should become dark and stormy, dew which had been deposited will disappear. In calm weather, if the sky be partially covered with clouds, more dew will appear than if it were entirely uncovered.

Dew probably begins in the country to appear upon grass, in places shaded from the sun, during clear and calm weather, soon after the heat of the atmosphere has declined, and continues to be deposited through the whole night, and for a little after sunrise. Its quantity will depend in some measure on the proportion of moisture in the atmosphere, and is consequently greater after rain than after a long tract of dry weather; and in Europe, with southerly and westerly winds, than with those which blow from the north and the east. The direction of the sea determines this relation of the winds to dew. For in Egypt, dew is scarcely ever observed except while the northerly or Etesian winds prevail. Hence also, dew is generally more abundant in spring and autumn, than in summer. And it is always very copious on those clear nights which are followed by misty mornings, which show the air to be loaded with moisture. And a clear morning, following a cloudy night, determines a plentiful deposition of the retained vapour. When warmth of atmosphere is compatible with clearness, as is the case in southern latitudes, though seldom in our country, the dew becomes much more copious, because the air then contains more moisture. Dew continues to form with increased copiousness as the night advances, from the increased refrigeration of the ground.

2. *On the cause of dew.*

Dew, according to Aristotle, is a species of rain, formed in the lower atmosphere, in consequence of its moisture being condensed by the cold of the night into minute drops. Opinions of this kind, says Dr. Wells, are still entertained by many persons, among whom is the very ingenious Professor Leslie. (*Relat. of Heat and Moisture*, p. 37. and 132.) A fact, however, first taken notice of by Gerstin, who published his treatise on dew in 1773, proves them to be erroneous; for he found that bodies a little elevated in the air, often become moist with dew, while similar bodies, lying on the ground, remain dry, though necessarily, from their position, *as* liable to be wetted, by whatever falls from the heavens, as the former. The above notion is perfectly refuted, by what will presently appear relative to metallic surfaces exposed to the air in a horizontal position, which remain dry, while every thing around them is covered with dew.

After a long period of drought, when the air was very still and the sky serene, Dr. Wells exposed to the sky, 28 minutes before sunset, previously weighed parcels of wool and swandown, upon a smooth, unpainted, and perfectly dry fir table, 5 feet long, 3 broad, and nearly 3 in height, which had been placed an hour before, in the sunshine, in a large level grass field. The wool, 12 minutes after sunset, was found to be 14° colder than the air, and to have acquired no weight. The swandown, the quantity of which was much greater than that of the wool, was at the same time 13° colder than the air, and was also without any additional weight. In 20 minutes more, the swandown was 14½ colder than the neighbouring air, and was still without any increase of its weight. At the same time the grass was 15° colder than the air four feet above the ground.

Dr. Wells, by a copious induction of facts derived from observation and experiment, establishes the proposition, *that bodies become colder than the neighbouring air* BEFORE *they are dewed.* The cold therefore which Dr. Wilson and Mr. Six conjectured to be the effect of dew, now appears to be its cause. But what makes the terrestrial surface colder than the atmosphere? The radiation or projection of heat into free space. Now the researches of Professor Leslie and Count Rumford have demonstrated, that different bodies project heat with very different degrees of force.

In the operation of this principle, therefore, conjoined with the power of a concave mirror of cloud or any other awning, to reflect or throw down again those calorific emanations which would be dissipated in a clear sky, we shall find a solution of the most mysterious phenomena of dew. Two circumstances must here be considered:—

1. The exposure of the particular surface to be dewed, to the free aspect of the sky.

2. The peculiar radiating power of the surface. 1. Whatever diminishes the view of the sky, as seen from the exposed body, obstructs the depression of its temperature, and occasions the quantity of dew formed upon it, to be less than would have occurred, if the exposure to the sky had been complete.

Dr. Wells bent a sheet of pasteboard into the shape of a penthouse, making the angle of flexure 90 degrees, and leaving both ends open. This was placed one evening with its ridge uppermost, upon a grass-plat in the direction of the wind, as well as this could be ascertained. He then laid 10 grains of white, and moderately fine wool, not artificially dried, on the middle part of that spot of the grass which was sheltered by the roof, and the same quantity on another part of the grass-plat, fully exposed to the sky. In the morning the sheltered wool was found to have increased in weight only 2 grains, but that which had been exposed to the sky 16 grains. He varied the experiment on the same night, by placing upright on the grass-plat a hollow cylinder of baked clay, 1 foot diameter, and 2½ feet high. On the grass round the outer edge of the cylinder, were laid 10 grains of wool, which in this situation, as there was not the least wind, would have received as much rain, as a like quantity of wool, fully exposed to the sky. But the quantity of moisture acquired by the wool, partially screened by the cylinder from the *aspect* of the sky was only about 2 grains, while that acquired by the same quantity fully exposed, was 16 grains. Repose of a body seems necessary to its acquiring its utmost coolness, and a full deposite of dew. Gravel walks and pavements project heat, and acquire dew, less readily than a grassy surface. Hence wool placed on the former has its temperature less depressed than on the latter, and therefore is less bedewed. Nor does the wool here attract moisture by capillary action on the grass, for the same effect happens if it be placed in a saucer. Nor is it by hygrometric attraction, for in a cloudy night, wool placed on an elevated board acquired scarcely any increase of weight.

If wool be insulated a few feet from the ground on a bad conductor of heat, as a board, it will become still colder than when in contact with the earth, and acquire fully more dew, than on the grass. At the windward end of the board, it is less bedewed than at the sheltered end, because in the former case, its temperature is nearer to that of the atmosphere. Rough and porous surfaces, as shavings of wood, take more dew than smooth and solid wood; and raw silk and fine cotton are more powerful in this respect than even wool. Glass projects heat rapidly, and is as rapidly coated with dew. But bright metals attract dew much less powerfully than other bodies. If we coat a piece of glass, partially, with bright tin-foil, or silver leaf, the uncovered portion of the glass quickly becomes cold by radiation, on exposure to a clear nocturnal sky, and acquires moisture; which beginning on those parts most remote from the metal, gradually approaches it. Thus also, if we coat outwardly a portion of a window pane with tin-foil, in a clear night, then moisture will be deposited inside, on every part except opposite to the metal. But if the metal be inside, then the glass under and beyond it will be sooner, or most copiously bedewed. In the first case, the tin-foil prevents the glass under it from dissipating its heat, and therefore it can receive no dew; in the second case, the tin-foil prevents the glass which it coats, from receiving the calorific influence of the apartment, and hence it is sooner refrigerated by external radiation, than the rest of the pane. Gold, silver, copper, and tin, bad radiators of heat, and excellent conductors, acquire dew with greater difficulty than platina, which is a more imperfect conductor; or than lead, zinc, and steel, which are better radiators.

Hence dew which has formed upon a metal will often disappear, while other substances in the neighbourhood remain wet; and a metal purposely moistened, will become dry, while neighbouring bodies are acquiring moisture. This repulsion of dew is communicated by metals to bodies in contact with, or near them. Wool laid on metal acquires less dew, than wool laid on the contiguous grass.

If the night becomes cloudy, after having been very clear, though there be no change with respect to calmness, a considerable alteration in the temperature of the grass always ensues. Upon one such night, the grass, after having been 12° colder than the air, became only 2° colder; the atmospheric temperature being the same at both observations. On a second night, grass became 9° warmer in the space of an hour and a half; on a third night, in less than 45 minutes, the temperature of the grass rose 15°, while that of the neighbouring air increased only 3½°. During a fourth night, the temperature of the grass at half past 9 o'clock was 32°. In 20 minutes afterwards, it was found to be 39°, the sky in the mean time having become cloudy. At the end of 20 minutes more, the sky being clear, the temperature of the grass was again 32°. A thermometer lying on a grass-plat, will sometimes rise several degrees, when a cloud comes to occupy the zenith of a clear sky.

When, during a clear and still night, different thermometers, placed in different situations, were examined, at the same time, those which were situated where most dew was formed, were always found to be the lowest. On dewy nights the temperature of the earth, half an inch or an inch beneath the surface, is always found much warmer than the grass upon it, or the air above it. The differences on five such nights, were from 12 to 16 degrees.

In making experiments with thermometers it is necessary to coat their bulbs with silver or gold leaf, otherwise their glassy surface indicates a lower temperature than that of the air, or the metallic plate it touches. Swandown seems to exhibit greater cold, on exposure to the aspect of a clear sky, than any thing else. When grass is 14° below the atmospheric temperature, swandown is commonly 15°. Fresh unbroken straw and shreds of paper, rank in this respect with swandown. Charcoal, lampblack, and rust of iron, are also very productive of cold. Snow stands 4° or 5° *higher* than swandown laid upon it in a clear night.

The following tabular view of observations by Dr. Wells, is peculiarly instructive:—

	6h. 45′	*7h.*	*7h.* 20′	*7h.* 40′	*8h.* 45′
Heat of the air 4 feet above the grass,	60½°	60¾°	59°	53°	54°
——— wool on a raised board, - -	53½	54½	51½	48½	44½
——— swandown on the same, - -	54½	53	51	47½	42½
——— surface of the raised board, -	58	57	55½	—	—
——— grass-plat, - - - - - - -	53	51	49½	49	42

The temperature always falls in clear nights, but the deposition of dew, depending on the moisture of the air, may occur or not. Now, if cold were the *effect* of dew, the cold connected with dew ought to be always proportional to the quantity of that fluid; but this is contradicted by experience. On the other hand, if it be granted that dew is water precipitated from the atmosphere, by the cold of the body on which it appears, the same degree of cold in the precipitating body may be attended with much, with little, or with no dew, according to the existing state of the air in regard to moisture, all of which circumstances are found really to take place. The actual precipitation of dew, indeed, ought to evolve heat.

A very few degrees of difference of temperature between the grass and the atmosphere is sufficient to determine the formation of dew, when the air is in a proper state. But a difference of even 30°, or more, sometimes exists, by the radiation of heat from the earth to the heavens. And hence, the air near the refrigerated surface must be colder than that somewhat elevated. Agreeably to Mr. Six's observations, the atmosphere, at the height of 220 feet, is often, upon such nights, 10° warmer than what it is seven feet above the ground. And had not the lower air thus imparted some of its heat to the surface, the latter would have been probably 40° under the temperature of the air.

Insulated bodies, or prominent points, are sooner covered with hoar-frost and dew than others; because the equilibrium of their temperature is more difficult to be restored. As aërial stillness is necessary to the cooling effect of radiation, we can understand why the hurtful effects of cold, heavy fogs, and dews, occur chiefly in hollow and confined places, and less frequently on hills. In like manner, the leaves of trees often remain dry throughout the night, while the blades of grass are covered with dew.

No direct experiments can be made to ascertain the manner in which clouds prevent or lessen the appearance of a cold at night, upon the surface of the earth, greater than that of the atmosphere. But it may be concluded from the preceding observations, that they produce this effect almost entirely by radiating heat to the earth, in return for that which they intercept in its progress from the earth towards the heavens. The heat extricated by the condensation of transparent vapour into cloud must soon be dissipated; whereas, the effect of greatly lessening or preventing altogether the appearance of a greater cold on the earth than that of the air, will be produced by a cloudy sky during the whole of a long night.

We can thus explain, in a more satisfactory manner than has usually been done, the sudden warmth that is felt in winter, when a fleece of clouds supervenes in clear frosty weather. Chemists ascribed this sudden and powerful change to the disengagement of the latent heat of the condensed vapours; but Dr. Wells's thermometric observations on the sudden alternations of temperature by cloud and clearness, render that opinion untenable. We find the atmosphere itself, indeed, at moderate elevations, of pretty uniform temperature, while bodies at the surface of the ground suffer great variations in *their* temperature. This single fact is fatal to the hypothesis derived from the doctrines of latent heat.

"I had often," says Dr. Wells, "smiled, in the pride of half knowledge, at the means frequently employed by gardeners, to protect tender plants from cold, as it appeared to me impossible that a thin mat, or any such flimsy substance, could prevent them from attaining the temperature of the atmosphere, by which alone I thought them liable to be injured. But when I had learned, that bodies on the surface of the earth become, during a still and serene night, colder than the atmosphere, by radiating their heat to the heavens, I perceived immediately a just reason for the practice, which I had before deemed useless. Being desirous, however, of acquiring some precise information on this subject, I fixed perpendicularly, in the earth of a grass-plat, four small sticks, and over their upper extremities, which were six inches above the grass, and formed the corners of a square whose sides were two feet long, I drew tightly a very thin cambric handkerchief. In this disposition of things, therefore, nothing existed to prevent the free passage of air from the exposed grass to that which was sheltered, except the four small sticks, and there was no substance to radiate downwards to the latter grass, except the cambric handkerchief."

The sheltered grass, however, was found nearly of the same temperature as the air, while the unsheltered was 5° or more colder. One night the fully exposed grass was 11° colder than the air; but the sheltered grass was only 3° colder. Hence we see the power of a very slight awning, to avert or lessen the injurious coldness of the ground. To have the full advantage of such protection from the chill aspect of the sky, the covering should not touch the subjacent bodies. Garden walls act partly on the same principle. Snow screens plants from this chilling radiation. In warm climates, the deposition of dewy moisture on animal substances hastens their putrefaction. As this is apt to happen only in clear nights, it was anciently supposed that bright moonshine favoured animal corruption.

From this rapid emission of heat from the surface of the ground, we can now explain the formation of ice during the night in Bengal, while the temperature of the air is above 32°. The nights most favourable for this effect, are those which are the calmest and most serene, and on which the air is so dry as to deposite little dew after midnight. Clouds and frequent changes of wind are certain preventives of congelation. 300 persons are employed in this operation at one place. The enclosures formed on the ground are four or five feet wide, and have walls only four inches high. In these enclosures, previously bedded with *dry* straw, broad, shallow, unglazed earthen pans are set, containing *unboiled pump-water*. Wind, which so greatly promotes evaporation, prevents the freezing altogether, and dew forms in a greater or less degree during the whole of the nights most productive of ice. If evaporation were concerned in the congelation, wetting the straw would promote it. But Mr. Williams, in the 83d vol. of the Phil. Trans. says, that it is *necessary* to the success of the process that the straw be *dry*. In proof of this he mentions, that when the straw becomes wet by accident it is renewed; and that when he purposely wetted it in some of the inclosures, the formation of ice there was always prevented. Moist straw both conducts heat and raises vapour from the ground, so as to obstruct the congelation. According to Mr. Leslie, water stands at the head of radiating substances. See Caloric.*

* **Diallage.** A species of the genus Schiller spar. Diallage has a grass-green colour. It occurs massive or disseminated. Lustre glistening and pearly. Cleavage imperfect double. Translucent. Harder than fluor spar. Brittle. Sp. gr. 3.1. It melts before the blow-pipe into a gray or greenish enamel. Its constituents are 50 silica, 11 alumina, 6 magnesia, 13 lime, 5.3 oxide of iron, 1.5 oxide of copper, 7.5 oxide of chrome.—*Vauquelin.* It occurs in the island of Corsica, and in Mont Rosa in Switzerland, along with saussurite. It is the *verde di Corsica duro* of artists, by whom it is fashioned into ring-stones and snuff-boxes. It is the smaragdite of Saussure.

The diallage in the rock is called *gabbro.**

* **Diamond.** Colours white and gray, also red, brown, yellow, green, blue, and black. The two last are rare. When cut it exhibits a beautiful play of colours in the sunbeam. It occurs in rolled pieces, and also crystallized: 1st, In the octohedron, in which each plane is inclined to the adjacent, at an angle of 109° 28′ 16″. The faces are usually curvilinear. This is the fundamental figure.—2d, A simple three-sided pyramid, truncated on all the angles. 3d, A segment of the octohedron. 4th, Twin crystal. 5th, Octohedron, with all the edges truncated. 6th, Octohedron, flatly bevelled on all the edges. 7th. Rhomboidal dodecahedron. 8th, Octohedron with convex faces, in which each is divided into three triangular ones, forming altogether 24 faces. 9th, Octohedron, in which each convex face is divided into six planes, forming 48 in all. 10th, Rhomboidal dodecahedron, with diagonally broken planes. 11th, A flat double three-sided pyramid. 12th, Very flat double three-sided pyramid, with cylindrical convex faces. 13th, Very flat double six-sided pyramid. 14th, Cube truncated on the edges. Crystal small. Surface rough, uneven, or streaked. Lustre splendent, and internally perfect adamantine. Cleavage octohedral, or parallel to the sides of an octohedron. Foliated structure. Fragments octohedral or tetrahedral. Semi transparent. Refracts single. Scratches all known minerals. Rather easily frangible. Streak gray. Sp. gr. 3.4 to 3.6. It consists of pure carbon, as we shall presently demonstrate. When rubbed, whether in the rough or polished state, it shows positive electricity; whereas rough quartz affords negative. It becomes phosphorescent on exposure to the sun, or the electric spark, and shines with a fiery light. In its power of refracting light it is exceeded only by red lead-ore, and orpiment. It reflects all the light falling on its posterior surface at an angle of incidence greater than 24° 13′, whence its great lustre is derived. Artificial gems reflect the half of this light. It occurs in imbedded grains and crystals in a sandstone in Brazil, which rests on chlorite and clay-slate. In India the *diamond bed* of clay is underneath beds of red or bluish-black clay; and also in alluvial tracts both in India and Brazil. For the mode of working diamond mines, and cutting and polishing diamonds, consult *Jameson's Mineralogy*, vol. i. p. 11.

The diamond is the most valued of all minerals. Dr. Wollaston has explained the cutting principle of glaziers' diamonds, with his accustomed sagacity, in the Phil. Trans. for 1816.

The weight, and consequently the value of diamonds, is estimated in carats, one of which is equal to four grains, and the price of one diamond, compared to that of another of equal colour, transparency, purity, form, &c. is as the squares of the respective weights. The average price of rough diamonds that are worth working, is about L. 2 for the first carat. The value of a cut diamond being equal to that of a rough diamond of double weight, exclusive of the price of workmanship, the cost of a wrought diamond of

1 carat is L.8
2 do. is $2^2 \times$ L.8, = 32
3 do. is $3^2 \times$ L.8, = 72
4 do is $4^2 \times$ L.8, = 128

100 do. is $100^2 \times$ L.8, = 80000.

This rule, however, is not extended to diamonds of more than 20 carats. The larger ones are disposed of at prices inferior to their value by that computation. The snow-white diamond is most highly prized by the jeweller. If transparent and pure, it is said to be of the first water.

The carat grain is different from the Troy grain. 156 carats make up the weight of one oz. troy; or 612 diamond grains are contained in the Troy ounce.

From the high refractive power of the diamond, MM. Biot and Arago supposed that it might contain hydrogen. Sir H. Davy, from the action of potassium on it, and its non-conduction of electricity, suggested in his third Bakerian lecture that a minute portion of oxygen might exist in it; and in his new experiments on the fluoric compounds, he threw out the idea, that it might be the carbonaceous principle, combined with some new, light, and subtle element, of the oxygenous and chlorine class.

This unrivalled chemist, during his residence at Florence in March 1814, made several experiments on the combustion of the diamond and of plumbago by means of the great lens in the cabinet of natural history, the same instrument as that employed in the first trials on the action of the solar heat on the diamond, instituted in 1694 by Cosmo III. Grand Duke of Tuscany. He subsequently made a series of researches on the combustion of different kinds of charcoal at Rome. His mode of investigation was peculiarly elegant, and led to the most decisive results.

He found that diamond, when strongly ignited by the lens, in a thin capsule of platinum, perforated with many orifices, so as to admit a free circulation of air, continued to burn with a steady brilliant red light, visible in the brightest sunshine, after it was withdrawn from the focus. Some time after the diamonds were removed out of the focus, indeed, a wire of platina that attached them to the tray was fused, though their weight was only 1.84 grains. His apparatus consisted of clear glass globes of the capacity of from 14 to 40 cubic inches, having single apertures to which stop-cocks were attached A small hollow cylinder of platinum was attached to one end of the stop-cock, and was mounted with the little perforated capsule for containing the diamond. When the experiment was to be made, the globe containing the capsule and the substance to be burned was exhausted by an excellent air pump, and pure oxygen, from chlorate of potash, was then introduced. The change of volume in the gas after combustion was estimated by means of a fine tube connected with a stop-cock, adapted by a proper screw to the stop-cock of the globe, and the absorption was judged of by the quantity of mercury that entered the tube, which afforded a measure so exact, that no alteration however minute could be overlooked. He had previously satisfied himself that a quantity of moisture, less than 1-100th of a grain, is rendered evident by deposition on a polished surface of glass; for a piece of paper weighing one grain was introduced into a tube of about four cubic inches capacity, whose exterior was slightly heated by a candle. A dew was immediately perceptible on the inside of the glass, though the paper, when weighed in a balance turning with 1 100th of a grain, indicated no appreciable diminution.

The diamonds were always heated to redness before they were introduced into the capsule. During their combustion, the glass globe was kept cool by the application of water to that part of it immediately above the capsule, and where the heat was greatest.

From the results of his different experiments, conducted with the most unexceptionable precision, it is demonstrated, that diamond affords no other substance by its combustion than pure carbonic acid gas; and that the process is merely a solution of diamond in oxygen, without any change in the volume of the gas. It likewise appears, that in the combustion of the different kinds of charcoal, water is produced; and that from the diminution of the volume of the oxygen, there is every reason to believe that the water is formed by the combustion of hydrogen existing in strongly ignited charcoal. As the charcoal from oil of turpentine left no residuum, no other cause but the presence of hydrogen can be assigned for the diminution occasioned in the volume of the gas during its combustion.

The only chemical difference perceptible between diamond and the purest charcoal is, that the last contains a minute portion of hydrogen; but can a quantity of an element, less in some cases than 1-50,000th part of the weight of the substance, occasion so great a difference in physical and chemical characters? The opinion of Mr. Tennant, that the difference depends on crystallization, seems to be correct. Transparent solid bodies are in general non-conductors of electricity; and it is probable that the same corpuscular arrangements which give to matter the power of transmitting and polarizing light, are likewise connected with its relations to electricity. Thus water, the hydrates of the alkalis, and a number of other bodies which are conductors of electricity when fluid, become non-conductors in their crystallized form.

That charcoal is more inflammable than the diamond, may be explained from the looseness of its texture, and from the hydrogen it contains. But the diamond appears to burn in oxygen with as much facility as plumbago, so that at least one distinction supposed to exist between the diamond and common carbonaceous substances is done away by these researches. The power possessed by certain carbonaceous substances of absorbing gases, and separating colouring matters from fluids, is probably mechanical, and dependent on their porous organic structure; for it belongs in the highest degree to vegetable and animal charcoal, and it does not exist in plumbago, coak, or anthracite.

The nature of the chemical difference between the diamond and other carbonaceous substances, may be demonstrated by igniting them in chlorine, when muriatic acid is produced from the latter, but not the former.—The visible acid vapour is owing to the moisture present in the chlorine uniting to the dry muriatic gas. But charcoal, after being intensely ignited in chlorine, is not altered in its conducting power or colour.—This circumstance is in favour of the opinion, that the minute quantity of hydrogen is not the cause of the great difference between the physical properties of the diamond and charcoal.*

It does not appear that any sum exceeding one hundred and fifty thousand pounds has been given for a diamond.

DICHROITE. See IOLITE.

DIGESTION. The slow action of a solvent upon any substance.

* **Digestion.** The conversion of food into *chyme* in the stomach of animals by the solvent power of the gastric juice. Some interesting researches have been lately made on this subject by Dr. Wilson Philip and Dr. Prout.

* *Phenomena, &c. of digestion in a rabbit.*—A rabbit which had been kept without food for twelve hours, was fed upon a mixture of bran and oats. About two hours afterwards it was killed, and examined immediately while still warm, when the following circumstances were noticed: The stomach was moderately distended, with a pulpy mass, which consisted of the food in a minute state of division, and so intimately mixed, that the different articles of which it was composed could be barely recognized. The digestive process, however, did not appear to have taken place equally throughout the mass, but seemed to be confined principally to the superficies, or where it was in contact with the stomach. The smell of this mass was peculiar, and difficult to be described. It might be denominated fatuous and disagreeable. On being wrapped up in a piece of linen, and subjected to moderate pressure, it yielded upwards of half a fluid ounce of an opaque reddish-brown fluid, which instantly reddened litmus paper very strongly. It instantly coagulated milk, and, moreover, seemed to possess the property of redissolving the curd and converting it into a fluid, very similar to itself in appearance. It was not coagulated by heat or acids; and, in short, did not exhibit *any evidence of an albuminous principle.* On being evaporated to dryness, and burned, it yielded very copious traces of an alkaline muriate, with slight traces of an alkaline phosphate and sulphate; also of various earthy salts, as the sulphate phosphate, and carbonate of lime.

"The first thing," says Dr. P. "which strikes the eye on inspecting the stomachs of rabbits which have lately eaten, is, that the new is never mixed with the old food. The former is always found in the centre surrounded on all sides by the old food, except that on the upper part between the new food and the smaller curvature of the stomach, there is sometimes little or no old food. If the old and the new food are of different kinds, and the animal be killed after taking the latter, unless a great length of time has elapsed after taking it, the line of separation is perfectly evident, so that the old may be removed without disturbing the new food.

"It appears that in proportion as the food is digested, it is moved along the great curvature, when the change in it is rendered more perfect, to the pyloric portion. The layer of food lying next the surface of the stomach, is first digested. In proportion as this undergoes the proper change, it is moved on by the muscular action of the stomach, and that next in turn succeeds to undergo the same change. Thus a continual motion is going on; that part of the food which lies next the surface of the stomach passing towards the pylorus, and the more central parts approaching the surface."

Dr. Philip has remarked, that the great end of the stomach is the part most usually found acted upon by the digestive fluids after death.

The following phenomena were observed by Dr. Prout:—

Comparative examination of the contents of the duodena of two dogs, one of which had been fed on vegetable food, the other on animal food only. The chymous mass from vegetable food (principally bread) was composed of a semi-fluid, opaque, yellowish-white part, containing another portion of a similar colour, but firmer consistence, mixed with it. Its specific gravity was 1.056. It showed no traces of a free acid, or alkali; but coagulated milk completely, when assisted by a gentle heat.

That from animal food was more thick and viscid than that from vegetable food, and its colour was more inclined to red. Its sp. gr. was 1.022. It showed no traces of a free acid or alkali; nor did it coagulate milk even when assisted by the most favourable circumstances.

On being subjected to analysis, these two specimens were found to consist of

	Chyme from vegetable food.	Chyme from animal food.
Water,	86.5	80.0
Gastric principle, united with the alimentary matters, and apparently constituting the chyme, mixed with excrementitious matter, - - -	6.0	15.8
Albuminous matter, partly consisting of fibrin, derived from the flesh on which the animal had been fed, -	—	1.3
Biliary principle, -	1.6	1.7
Vegetable gluten? -	5.0	—
Saline matters, -	0.7	0.7
Insoluble residuum,	0.2	0.5
	100.0	100.0

Very similar phenomena were observed in other instances. But when the animal was opened at a longer period after feeding, Dr. Prout generally found much stronger evidences of albuminous matter, not only in the duodenum, but nearly throughout the whole of the small intestines. The quantity, however, was generally very minute in the ileum; and where it enters the cœcum, so traces of this principle could be perceived. See **Sanguification.***

Digestive Salt. Muriate of potash.

Digester. The digester is an instrument invented by Mr. Papin about the beginning of the last century. It is a strong vessel of copper or iron, with a cover adapted to screw on with pieces of felt or paper interposed. A valve with a small aperture is made in the cover, the stopper of which valve may be more or less loaded either by actual weights, or by pressure from an apparatus on the principle of the steelyard.

The purpose of this vessel is to prevent the loss of heat by evaporation. The solvent power of water when heated in this vessel is greatly increased.

* **Diopside.** A sub-species of oblique edged augite. Its colour is greenish-white. It occurs massive, disseminated, and crystallized: 1. In low oblique four-sided prisms. 2. The same, truncated on the acute lateral edges, bevelled on the obtuse edges, and the edge of the bevelment truncated. 3. Eight-sided prisms. The broader lateral planes are deeply longitudinally streaked, the others are smooth. Lustre shining and pearly. Fracture uneven. Translucent.—As hard as augite. Sp. gr. 3. 3. It melts with difficulty before the blow-pipe. It consists of 57.5. silica, 18.25 magnesia 16.5 lime, 6 iron and manganese.—*Laugier.* It is found in the hill Ciarmetta in Piedmont; also in the black rock at Mussa, near the town of Ala, in veins along with epidote or pistacite, and hyacinth-red garnets. It is the Alalite and Mussite of Bonvoisin.*

* **Dioptase.** Emerald copper-ore.*

* **Dippel's** animal oil, an oily matter obtained in the igneous decomposition of horns in a retort. Rectified, it becomes colourless, aromatic, and as light and volatile as ether. It changes sirup of violets to a green from its holding a little ammonia in solution.*

* **Dipyre.** Schmelzstein.

This mineral is distinguished by two characters; it is fusible with intumescence by the blow-pipe, and it emits on coals a faint phosphorescence. It is found in small prisms, united in bundles, of a grayish or reddish-white. These crystals are splendent, hard enough to scratch glass; their longitudinal fracture is lamellar, and their cross fracture conchoidal. Its sp. gr. is 2.63. The primitive form appears to be the regular six-sided prism. It consists of 60 silica, 24 alumina, 10 lime, 2 water, and 4 loss.—*Vauquelin.* It occurs in a white or reddish steatite, mingled with sulphuret of iron, on the right bank of the torrent of Mauléon in the western Pyrenees.*

* **Distillation.** The vaporization and subsequent condensation of a liquid, by means of an alembic, or still and refrigeratory, or of a retort and a receiver. The old distinctions of *distillatio per latus, per ascensum,* and *per decensum,* are now discarded.

Under **Laboratory,** a drawing and description of a large still of an ingenious construction is given. The late celebrated Mr. Watt having ascertained, that liquids boiled *in vacuo* at much lower temperatures than under the pressure of the atmosphere, applied this fact to distillation; but he seems, according to Dr. Black's report of the experiment, to have found no economy of fuel in this elegant process; for the latent heat of the vapour raised *in vacuo,* appeared to be considerably greater than that raised in ordinary circumstances. Mr. Henry Tritton has lately contrived a very simple apparatus for performing this operation *in vacuo*; and though no saving of fuel should be made, yet superior flavour may be secured to the distilled spirits and essential oils, in consequence of the moderation of the heat. The still is of the common form; but instead of being placed immediately over a fire, it is immersed in a vessel containing hot water. The pipe from the capital bends down and terminates in a cylinder or barrel of metal plunged in a cistern of cold liquid. From the bottom of this barrel, a pipe proceeds to another of somewhat larger dimensions, which is surrounded with cold water, and furnished at its top with an exhausting syringe.

The pipe from the bottom of the still, for emptying it, and that from the bottom of each barrel, are provided with stop-cocks. Hence, on exhausting the air, the liquid will distil rapidly, when the body of the alembic is surrounded with boiling water. When it is wished to withdraw a portion of the distilled liquor, the stop-cock at the bottom of the first receiver is shut, so that on opening that at the second, in order to empty it, the vacuum is maintained in the still. It is evident that the first receiver may be surrounded with a portion of the liquid to be distilled, as I have already explained in treating of alcohol. By this means the utmost economy of fuel may be observed.

The term *distillation,* is often applied in this country, to the whole process of converting malt or other saccharine matter, into spirits or alcohol.

In making malt whiskey, one part of bruised malt, with from four to nine parts of barley meal, and a proportion of seeds of oats, corresponding to that of the raw grain, is infused in a mash-tun of cast iron, with from 12 to 13 wine gallons of water, at 150° Fahr. for every bushel of the mixed farinaceous matter. The agitation then given by manual labour or machinery to break down and equally diffuse the lumps of meal, constitutes the process of *mashing.* This operation continues two hours or upwards, according to the proportion of unmalted barley;

during which the temperature is kept up, by the effusion of seven or eight additional gallons of water, a few degrees under the boiling temperature. The infusion termed *wort* having become progressively sweeter, is allowed to settle for two hours, and is run off from the top, to the amount of about one-third the bulk of water employed. About eight gallons more of water, a little under 200° F. are now admitted to the residuum, *infused* for nearly half an hour with agitation, and then left to subside for an hour and a half, when it is drawn off. Sometimes a third affusion of boiling water, equal to the first quantity, is made, and this infusion is generally reserved to be poured on new *farina*; or it is concentrated by boiling and added to the former liquors. In Scotland, the distiller is supposed by law, to extract per cent 14 gallons of spirits, sp. gr. 0.91917, or 1 to 10 over proof, and must pay duty accordingly. Hence, his wort must have at least the strength of 55½ pounds of saccharine matter, per barrel, previous to letting it down into the fermenting tun; and the law does not permit it to be stronger than 75 pounds. Every gallon of the above spirits contains 4.6 pounds of alcohol, sp. gr. 0.825, and requires for its production the complete decomposition of twice 4.6 pounds of sugar = 9.2 pounds. But since we can never count on decomposing above four-fifths of the saccharine matter of wort, we must add one-fifth to 9.2 pounds, when we shall have 11½ pounds for the weight of saccharine matter, equivalent in practice to one gallon of the legal spirits. Hence, the distiller is compelled to raise the strength of his wort up to nearly 70 pounds per barrel as indicated by his saccharometer. This concentration is to be regretted, as it materially injures the flavour of the spirit. The thinner worts of the Dutch, give a decided superiority to their alcohols. At 62 pounds per barrel, we should have about 12 per cent of spirits of the legal standard.

To prevent acetification, it is necessary to cool the worts down to the proper fermenting temperature of 70°, or 65°, as rapidly as possible. Hence, they are pumped immediately from the mash-tun into extensive wooden troughs, two or three inches deep, exposed in open sheds to the cool air; or they are made to traverse the convolutions of a pipe, immersed in cold water.—The wort being now run into the fermenting tun, yeast is introduced and added in nearly equal successive portions, during three days; amounting in all to about one gallon, for every two bushels of farinaceous matter. The temperature rises in three or four days, to its maximum of 80°; and at the end of 10 or 12 days the fermentation is completed; the tuns being closed up during the last half of the period. The distillers do not collect the yeast from their fermenting tuns, but allow it to fall down, on the supposition that it enhances the quantity of alcohol.

The specific gravity of the liquid has now probably sunk from 1.060, that of wort equivalent to about 56 pounds per barrel, to 1.005, or 1.000; and consists of alcohol mixed with undecomposed saccharine and farinaceous matter. The larger the proportion of alcohol, the more sugar will be preserved unchanged; and hence the impolicy of the present laws on distillation.

Some years ago, when the manufacturer paid a duty for the season, merely according to the measurement of his still, it was his interest to work it off with the utmost possible speed. Hence the form of still and furnace described under LABORATORY, was contrived by some ingenious Scotch distillers, by which means they could work off in less than four minutes, and recharge, an 80 gallon still; an operation which had a few years before lasted several days, and which the vigilant framers of the law, after recent investigation, deemed possible only in eight minutes. The waste of fuel was however great. The duties being now levied on the product of spirit, the above contest against time no longer exists. It has been supposed, but I think on insufficient grounds, that quick distillation injures the flavour of spirits. This I believe to depend, almost entirely, on the mode of conducting the previous fermentation.

In distilling off the spirit from the fermented wort or wash, a hydrometer is used to ascertain its progressive diminution of strength, and when it acquires a certain weakness, the process is stopped by opening the stop-cock of the pipe, which issues from the bottom of the still, and the spent wash is removed. There is generally introduced into the still, a bit of soap, whose oily principle spreading on the surface of the boiling liquor, breaks the large bubbles, and of course checks the tendency to froth up. The spirits of the first distillation, called in Scotland *low wines*, are about 0.975 sp. gravity, and contain nearly 20 per cent of alcohol of 0.825. Redistillation of the *low wines*, or *doubling*, gives at first the fiery spirit called first-shot, milky and crude, from the presence of a little oil. This portion is returned into the low wines, What flows next is clear spirit, and is received in one vessel, till its density diminish to a certain degree. The remaining spirituous liquor, called *faints*, is mixed with *low wines*, and subjected to another distillation.

The manufacturer is hindered by law from sending out of his distillery, stronger spirits than 1 to 10 over hydrometer proof, equivalent to sp. gr. 0.90917; or weaker spirits than 1 in 6 under proof, whose sp. gr. is 0.9385.

The following is said to be the Dutch mode of making Geneva:—

One cwt. of barley malt and two cwts. of rye meal are mashed with 460 gallons of water, heated to 162°F. After the *farinæ* have been infused for a sufficient time, cold water is added, till the wort becomes equivalent to 45 pounds of saccharine matter per barrel. Into a vessel of 500 gallons capacity, the wort is now put at the temperature of 80°, with half a gallon of yeast. The fermentation instantly begins, and is finished in 48 hours, during which the heat rises to 90°. The wash, not reduced lower than 12 or 15 pounds per barrel, is put into the still along with the grains. Three distillations are required; and at the last, a few juniper berries and hops are introduced to communicate flavour. The attenuation of 45 pounds in the wort, to only 15 in the wash shows that the fermentation is here very imperfect and uneconomical; as indeed we might infer from the small proportion of yeast, and the precipitancy of the process of fermentation. On the other hand, the very large proportion of porter yeast in a corrupting state, used by the Scotch distillers, cannot fail to injure the flavour of their spirits.

Rum is obtained from the fermentation of the coarsest sugar and molasses in the West Indies, dissolved in water in the proportion of nearly a pound to the gallon. The yeast is procured chiefly from the rum *wort*. The preceding details give sufficient instruction for the conduct of this modification of the process.

Sykes' hydrometer is now universally used in the collection of the spirit revenue in Great Britain. It consists, first of a flat stem, 3.4 inches long, which is divided on both sides into 11 equal parts, each of which is subdivided into two, the scale being numbered from 0 to 11. This stem is soldered into a brass ball 1.6 inch in diameter, into the under part of which is fixed a small conical stem 1.13 inch long, at whose end is a pear-shaped loaded bulb, half an inch in diameter. The whole instrument, which is made of brass, is 6.7 inches long. The instrument is accompanied with 8 circular weights, numbered 10, 20, 30, 40, 50, 60, 70, 80, and another weight of the form of a parallelopiped. Each of the circular weights is cut into its centre, so that it can be placed on the inferior conical stem, and slid down to the bulb; but in consequence of the enlargement of the cone, they cannot slip off at the bottom, but must be drawn up to the thin part for this purpose. The square weight of the form of a parallelopiped, has a square notch in one of its sides, by which it can be placed on the summit of the stem. In using this instrument, it is immersed in the spirit, and pressed down by the hand to O, till the whole divided part of the stem be wet. The force of the hand required to sink it, will be a guide in selecting the proper weight. Having taken one of the circular weights, which is necessary for this purpose, it is slipped on the conical stem. The instrument is again immersed and pressed down as before to O, and is then allowed to rise and settle, at any point of the scale. The eye is then brought to the level of the surface of the spirit, and the part of the stem cut by the surface, as *seen from below*, is marked. The number thus indicated by the stem is added to the number of the weight employed, and with this sum at the side, and the temperature of the spirits at the top, the strength *per cent* is found in a table of 6 quarto pages. "The strength is expressed in numbers denoting the excess or deficiency per cent of proof-spirit in any sample, and the number itself (having its decimal point removed two places to the left) becomes a factor, whereby the gauged content of a cask or vessel of such spirit being multiplied, and the product being added to the gauged content, if over proof, or deducted from it if under proof, the result will be the actual quantity of proof spirit contained in such cask or vessel."*

DISTHENE. See CYANITE.

* DISTINCT CONCRETIONS. A term in MINERALOGY.*

DOCIMASTIC ART. This name is given to the art of assaying. See ASSAY, BLOWPIPE, ANALYSIS, and the several metals.

*DOLOMITE. Of this calcareo-magnesian carbonate, we have three sub-species.

1. Dolomite, of which there are two kinds.

§ 1st. *Granular Dolomite.*

White granular. It occurs massive, and in fine granular distinct concretions, loosely aggregated. Lustre glimmering and pearly. Fracture in the large, imperfect slaty. Faintly translucent. As hard as fluor. Brittle Sp. gr. 2.83. It effervesces feebly with acids. Phosphorescent on heated iron, or by friction. Its constituents are 46.5 carbonate of magnesia, 52.08 carbonate of lime, 0.25 oxide of manganese, and 0.5 oxide of iron. *Klaproth.* Beds of dolomite, containing tremolite, occur in the island of Iona, in the mountain group of St. Gothard, in the Appenines, and in Carinthia. A beautiful white variety used by ancient sculptors, is found in the Isle of Tenedos. *Jameson.*

The *flexible* variety was first noticed in the Borghese palace at Rome; but the other varieties of dolomite, and also common granular limestone, may be rendered flexible, by exposing them in thin and long slabs to a heat of 480° Fahr. for 6 hours.

§ 2d, *Brown Dolomite*, or magnesian limestone of Tennant.

Colour, yellowish-gray and yellowish-brown. Massive, and in minute granular concretions. Lustre internally glistening. Fracture splintery. Translucent on the edges. Harder than calcareous spar. Brittle. Sp. gr. of crystals, 2.8. It dissolves slowly, and with feeble effervescence; and when calcined, it is long in re-absorbing carbonic acid from the air. Its constituents are, lime 29.5, magnesia 20.3, carbonic acid 47.2. Alumina and iron 0.8. *Tennant*. In the north of England it occurs in beds of considerable thickness, and great extent, resting on the Newcastle coal formation. In the Isle of Man, it occurs in a limestone which rests on gray-wacke. It occurs in trap-rocks in Fifeshire. When laid on land after being calcined, it prevents vegetation, unless the quantity be smalll.

To the preceeding variety we must refer a *flexible dolomite* found near Tinmouth Castle. It is yellowish-gray, passing into cream-yellow. Massive. Dull. Fracture earthy. Opaque. Yields readily to the knife. In thin plates, very flexible. Sp. gr. 2.54; but the stone is porous. It dissolves in acids as readily as common carbonate of lime. Its constituents are said to be 62 carbonate of lime, and 36 carbonate of magnesia. When made moderately dry, it loses its flexibility; but when either very moist or very dry, it is very flexible.

2d. *Columnar Dolomite*. Colour pale grayish-white. Massive, and in thin prismatic concretions. Cleavage imperfect. Fracture uneven. Lustre vitreous, inclining to pearly. Breaks into acicular fragments. Feebly translucent. Brittle. Sp. gr. 2.76. Its constituents are 51 carbonate of lime, 47 carbonate of magnesia, 1 carbonated hydrate of iron. It occurs in serpentine in Russia.

3d, *Compact Dolomite*, or Gurhofite. Colour snow-white. Massive. Dull. Fracture flat conchoidal. Slightly translucent on the edges. Semi-hard. Difficultly frangible. Sp. gr. 2.76. When pulverized, it dissolves with effervescence in hot nitric acid. It consists of 70.5 carbonate of lime, and 29.5 carbonate of magnesia. It occurs in veins in serpentine rocks, near Gurhoff, in Lower Austria.*

DRACO-MITIGATUS. Calomel. See MERCURY.*

*DRAGON'S BLOOD. A brittle dark red coloured resin, imported from the East Indies, the product of *pterocarpus draco*, and *dracœna draco*. It is insoluble in water, but soluble in a great measure in alcohol. The solution imparts a beautiful red stain to hot marble. It dissolves in oils. It contains a little benzoic acid.*

DRAWING SLATE. Black chalk. Colour grayish black. Massive. Lustre of the principal fracture, glimmering; of the cross fracture, dull. Fracture of the former slaty, of the latter, fine earthy. Opaque. It writes. Streak same colour, and glistening. Very soft. Sectile. Easily frangible. It adheres slightly to the tongue,—Feels fine, but meagre. Sp. gr. 2.11. It is infusible. Its constituents are, silica 64.06, alumina 11, carbon 11, water 7.2, iron 2.75 It occurs in beds in primitive and transition clay-slate, also in secondary formations. It is found in the coal formation of Scotland, and in most countries. It is used in crayon-painting. The trace of bituminous shale is brownish and irregular; that of black chalk is regular and black. The best kind is found in Spain, Italy, and France.

DUCTILITY. That property or texture of bodies, which renders it practicable to draw them out in length, while their thickness is diminished without any actual fracture of their parts. This term is almost exclusively applied to metals.

Most authors confound the words malleability, laminability, and ductility together, and use them in a loose indiscriminate way; but they are very different. Malleability is the property of a body which enlarges one or two of its three dimensions, by a blow or pressure very suddenly applied. Laminability belongs to bodies extensible in dimension by a gradually applied pressure. And ductility is properly to be attributed to such bodies as can be rendered longer and thinner by drawing them through a hole of less area than the transverse section of the body so drawn.

DYEING. The art of dyeing consists in fixing upon cloths of various kinds any colour which may be required, in such a manner as that they shall not be easily altered by those agents, to which the cloth will most probably be exposed.

As there can be no cause by which any colouring matter can adhere to any cloth, except an attraction subsisting between the two substances, it must follow, that there will be few tinging matters capable of indelibly or strongly attaching themselves by simple application.

Dyeing is therefore a chemical art.

The most remarkable general fact in the art of Dyeing, consists in the different degrees of facility, with which animal and vegetable substances attract and retain colouring matter, or rather the degree of facility with which the dyer finds he can tinge them with any intended colour. The chief materials of stuff to be dyed are wool, silk, cotton, and linen, of which the former two are more easily dyed than the latter. This has been usually attributed to their greater attraction to the tinging matter.

Wool is naturally so much disposed to combine with colouring matter, that it requires but little preparation for the immediate process of dyeing; nothing more being required than to cleanse it, by scouring, from a fatty substance, called the yolk, which is contained in the fleece. For this purpose an alkaline liquor is necessary; but as alkalis injure the texture of the wool, a very weak solution may be used. For if more alkali were present than is sufficient to convert the yolk into soap, it would attack the wool itself. Putrid urine is therefore generally used, as being cheap, and containing a volatile alkali, which, uniting with the grease, renders it soluble in water.

Silk, when taken from the cocoon, is covered with a kind of varnish, which, because it does not easily yield either to water or alcohol, is usually said to be soluble in neither. It is therefore usual to boil the silk with an alkali, to disengage this matter. Much care is necessary in this operation, because the silk itself is easily corroded or discoloured. Fine soap is commonly used, but even this is said to be detrimental; and the white China silk, which is supposed to be prepared without soap, has a lustre superior to that of Europe. Silk loses about one-fourth of its weight by being deprived of its varnish. See BLEACHING.

The intention of the previous preparations seems to be of two kinds. The first to render the stuff or material to be dyed as clear as possible, in order that the aqueous fluid to be afterward applied, may be imbibed, and its contents adhere to the minute internal surfaces. The second is, that the stuff may be rendered whiter and more capable of reflecting the light, and consequently enabling the colouring matter to exhibit more brilliant tints.

Some of the preparations, however, though considered merely as preparative, do really constitute part of the dyeing processes themselves. In many instances a material is applied to the stuff, to which it adheres; and when another suitable material is applied, the result is some colour desired. Thus we might dye a piece of cotton black, by immersing it in ink; but the colour would be neither good nor durable, because the particles of precipitated matter, formed of the oxide of iron and acid of galls, are already concreted in masses too gross either to enter the cotton, or to adhere to it with any considerable degree of strength. But if the cotton be soaked in an infusion of galls, then dried, and afterward immersed in a solution of sulphate of iron (or other ferruginous salt), the acid of galls being every where diffused through the body of the cotton, will receive the particles of oxide of iron, at the very instant of their transmission from the fluid, or dissolved to the precipitated or solid state, by which means a perfect covering of the black inky matter will be applied in close contact with the surface of the most minute fibres of the cotton. This dye will therefore not only be more intense, but likewise more adherent and durable.

The French dyers, and after them the English, have given the name of *mordant* to those substances which are previously applied to piece goods, in order that they may afterward take a required tinge or dye.

It is evident, that if the mordant be universally applied over the whole of a piece of goods, and this be afterward immersed in the dye, it will receive a tinge over all its surface; but if it be applied only in parts, the dye will strike in those parts only. The former process constitutes the art of dyeing, properly so called; and the latter, the art of printing woollens, cottons, or linens, called calico-printing.

In the art of printing piece goods, the mordant is usually mixed with gum or starch, and applied by means of blocks or wooden engravings in relief, or from copper plates, and the colours are brought out by immersion in vessels filled with suitable compositions. Dyers call the latter fluid the bath The art of printing affords many processes, in which the effect of mordants, both simple and compound, is exhibited. The following is taken from Berthollet.

The mordant employed for linens, intended to receive different shades of red, is prepared by dissolving in eight pounds of hot water, three pounds of alum, and one pound of acetate of lead, to which two ounces of potash, and afterward two ounces of powdered chalk, are added.

In this mixture the sulphuric acid combines with the lead of the acetate and falls down, because insoluble, while the argillaceous earth of the alum unites with the acetic acid disengaged from the acetate of lead. The mordant therefore consists of of an argillaceous acetic salt, and the small quantities of alkali and chalk serve to neutralize any disengaged acid, which might be contained in the liquid.

Several advantages are obtained by thus changing the acid of the alum. First, the argillaceous earth is more easily disengaged from the acetic acid, in the subsequent processes, than it would have been from the sulphuric. Secondly, this weak acid does less harm when it comes to be disengaged by depriving it of its earth. And thirdly, the acetate of alumina not being crystallizable like the sulphate, does not separate or curdle by drying on the face of the blocks for printing, when it is mixed with gum or starch.

When the design has been impressed by transferring the mordant from the face of the wooden blocks to the cloth, it is then put into a bath of madder, with proper attention, that the whole shall be equally exposed to this fluid. Here the piece becomes of a red colour, but deeper in those places where the mordant was applied. For some of the argillaceous earth had before quitted the acetic acid, to combine with the cloth; and this serves as an intermedium to fix the colouring matter of the madder, in the same manner as the acid of galls, in the former instance, fixed the particles of oxide of iron. With the piece in this state, the calico-printer has only therefore to avail himself of the difference between a fixed and a fugitive colour. He therefore boils the piece with bran, and spreads it on the grass. The fecula of the bran takes up part of the colour, and the action of the sun and air renders more of it combinable with the same substance.

In other cases, the elective attraction of the stuff to be dyed has a more marked agency. A very common mordant for woollens is made by dissolving alum and tartar together; neither of which is decomposed, but may be recovered by crystallization upon evaporating the liquor. Wool is found to be capable of decomposing a solution of alum, and combining with its earth; but it seems as if the presence of disengaged sulphuric acid served to injure the wool, which is rendered harsh by this method of treatment, though cottons and linens are not, which have less attraction for the earth. Wool also decomposes the alum, in a mixture of alum and tartar; but in this case there can be no disengagement of sulphuric acid, as it is immediately neutralized by the alkali of the tartar.

Metallic oxides have so great an attraction for many colouring substances, that they quit the acids in which they were dissolved, and are precipitated in combination with them. These oxides are also found by experiment to be strongly disposed to combine with animal substances; whence in many instances they serve as mordants, or the medium of union between the colouring particles and animal bodies.

The colours which the compounds of metallic oxides and colouring particles assume, then, are the product of the colour peculiar to the colouring particles, and of that peculiar to the metallic oxide.

* The following are the dye-stuffs used by the calico-printers for producing fast colours. The mordants are thickened with gum, or calcined starch, and applied with the block, roller, plates, or pencil.

1. *Black.* The cloth is impregnated with acetate of iron (iron liquor), and dyed in a bath of madder and logwood.

2. *Purple.* The preceding mordant of iron, diluted; with the same dyeing bath.

3 *Crimson.* The mordant for purple, united with a portion of acetate of alumina, or red mordant, and the above bath.

4. *Red.* Acetate of alumina is the mordant, (see ALUMINA), and madder is the dye-stuff.

5. *Pale red* of different shades. The preceding mordant diluted with water, and a weak madder bath.

6. *Brown* or *Pompadour.* A mixed mordant, containing a somewhat larger proportion of the red than of the black; and the dye of madder.

7. *Orange.* The red mordant; and a bath first of madder, and then of quercitron.

8. *Yellow.* A strong red mordant; and the quercitron bath, whose temperature should be considerably under the boiling point of water.

9. *Blue.* Indigo, rendered soluble and greenish-yellow coloured, by potash and orpiment. It recovers its blue colour, by exposure to air, and thereby also fixes firmly on the cloth. An indigo vat is also made, with that blue substance, diffused in water with quicklime and copperas. These substances are supposed to deoxidize indigo, and at the same time to render it soluble.

Golden-dye. The cloth is immersed alternately in a solution of copperas and lime-water. The protoxide of iron precipitated on the fibre, soon passes by absorption of atmospherical oxygen, into the golden-coloured deutoxide.

Buff. The preceding substances, in a more dilute state.

Blue vat, in which white spots are left on a blue ground of cloth, is made, by applying to these points a paste composed of a solution of sulphate of copper and pipe-clay; and after they are dried, immersing it stretched on frames for a definite number of minutes, in the yellowish-green vat, of 1 part of indigo, 2 of copperas, and 2 of lime, with water.

Green. Cloth dyed blue, and well washed, is imbued with the aluminous acetate, dried, and subjected to the quercitron bath.

In the above cases, the cloth, after receiving the mordant paste, is dried, and put through a mixture of cow dung and warm water. It is then put into the dyeing vat or copper.

Fugitive Colours.

All the above colours are given, by making decoctions of the different colouring woods; and receive the slight degree of fixity they possess, as well as great brilliancy, in consequence of their combination or admixture with the nitro-muriate of tin.

1. *Red* is frequently made from Brazil and Peachwood.

2. *Black.* A strong extract of galls, and deuto-nitrate of iron.

3. *Purple.* Extract of logwood and the deuto-nitrate.

4. *Yellow.* Extract of quercitron bark, or French berries, and the tin solution.

5. *Blue.* Prussian blue and solution of tin.